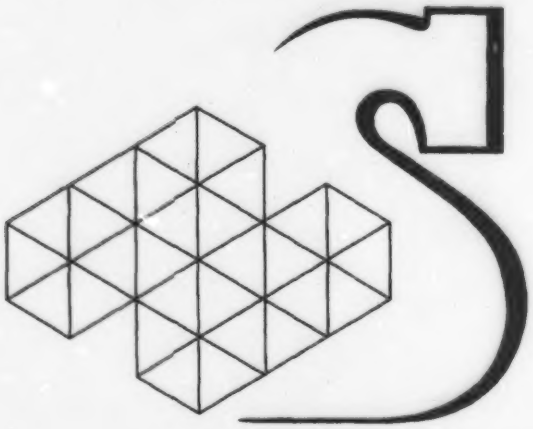

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Generation III Prototype Fragmentation Vest Human Factors Confirmatory Trial

PWGSC Contract No. W7711-7-7429/01-SRV
Order No. 7429-09

November 2000

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Generation III Prototype Fragmentation Vests Human Factors Confirmatory Trial

Location: CFB Petawawa **Trial Date:** 01-02 September 1999

By

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PWGSC Contract No. W7711-7-7429/-09 SRV
on behalf of
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November 2000

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Résumé

En 1991, les Forces canadiennes (FC) ont conçu et fabriqué un gilet pare-éclats pour la protection du personnel de notre force terrestre contre les menaces balistiques pendant les opérations militaires. Les défaillances opérationnelles de ce gilet ont été signalées peu après son introduction dans le service; on parle ici de rigidité excessive, de mobilité réduite et d'incompatibilité avec les casques, les viseurs et l'équipement personnel de transport de charges du service. Afin de résoudre ces problèmes, une série d'études sur les facteurs humains (FH) ont été entreprises pour développer un nouveau modèle de gilet pare-éclats. Le modèle de base terminé, on a recommandé un essai détaillé d'ajustement, pour déterminer les grandeurs requises et les tolérances d'ajustement, et un essai de confirmation, pour évaluer l'efficacité de toute modification de conception.

Un essai d'un jour et demi sur le terrain a été mené à la BFC Petawawa du 1er au 2 septembre 2000 (référence F) afin de confirmer les modifications de conception apportées au gilet pare-éclats Generation III. Deux systèmes de gilet pare-éclats ont été évalués par 11 participants mâles de la force régulière. Une comparaison partielle des conditions des gilets a été effectuée par mesures répétées. Les essais usuels consistaient à évaluer l'ajustement; la compatibilité entre arme, vêtements et équipement; l'exécution des tâches liées aux obstacles et au combat; les tâches au combat; l'aise et l'acceptation par l'utilisateur.

D'après les résultats de cet essai de confirmation, un certain nombre des modifications de conception formulées auparavant ont été reçues et d'autres, rejetées. Les recommandations qui suivent ont été confirmées comme étant favorables : supprimer le tissu autour de l'ouverture des manches; fournir un col détachable; couvrir les épaulettes et les points recevant les épaulières d'un tissu non glissant; allonger la bande de Velcro d'ajustement latéral qui se trouve sur le devant du gilet. Les modifications proposées pour les épaulettes n'ont pas été retenues. On recommande d'utiliser les épaulettes du gilet Gen III (juillet 98) à l'endroit où se trouvent les boutons pressions des épaulettes du gilet Gen III (août 99). La rigidité du tissu porteur du gilet essayé a été jugée acceptable. Le cordura enduit par léchage de 500 et de 1000 tex a éliminé tous les problèmes associés au tissu de base DCAM qui a été utilisé à l'essai d'ajustement. Les résultats de cet essai de confirmation révèlent également que la conception du gilet a besoin d'être raffinée davantage, mais on a recommandé d'attendre jusqu'à ce que l'essai de validité de l'offre soit terminé avant d'apporter d'autres modifications.

Executive Summary

In 1991, the Canadian Forces (CF) designed and built a fragmentation vest for the protection of our Land Forces personnel against ballistic threats during military operations. Operational deficiencies with the fragmentation vest were reported shortly after introduction into service; these deficiencies included: excessive stiffness, degraded mobility, and incompatibility with helmets, weapon sights and in-service personal load carriage equipment. In order to resolve the in-service vest deficiencies, a series of human factors (HF) investigations were undertaken to develop a new fragmentation vest design. Once a basic design was finalized it was recommended that a detailed fit test should be undertaken to determine tariff and fit boundaries and a confirmatory trial should be undertaken to evaluate the efficacy of any design changes.

A one and one-half-day field trial was undertaken at CFB Petawawa over the period 01 to 02 September 2000 (Reference F) to confirm design changes to the Generation III fragmentation vest. Two fragmentation vest systems were evaluated by a total of 11 regular force male participants. A partially repeated measures comparison between vest conditions was performed. The human factors tests included assessments of fit; weapon, clothing and equipment compatibility; performance of selected obstacle and combat tasks; battle tasks; comfort; and user acceptance.

Based on the results of this confirmatory trial a number of previously recommended design changes were supported while some were rejected. The following recommended changes were confirmed as being beneficial: removal of the material around the arm openings; provision of a removable collar; provision of slip resistant material on shoulder pads and butt rest points; and lengthening of the side adjustment strap Velcro pile on the front of the vest. The proposed change to the shoulder pad design was not supported. It is recommended that the Gen III (July 98) shoulder pad design should be utilized with the Generation III (Aug 99) shoulder pad snap locations. The trialled vest carrier shell stiffness was found to be acceptable. The 500 and 1000 denier cordura with a kiss coating eliminated many of the problems associated with the CADPAT shell material utilized in the fitting trial. The results of this confirmatory trial also indicate the need for additional refinements to the vest design but it was recommended that any other modifications wait until after the bid acceptance trial.

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1. Introduction

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B. Human Factors Review of Possible Approaches to the G2122 Fragmentation Vest Modification Programme (Phase I) -Human Systems Report Contract No. W7711-2-7151-04, dated 3 December 1993. C. Human Factors Evaluation of Possible Approaches to the G2122 Fragmentation Vest Modification Programme (Phase II) - Human Systems Report Contract No. W7711-2-7151/04 dated 31 March 1994.

D. Human Factors Review of Nine Fragmentation Vest Prototypes - Human Systems Report Contract No. W7701-3-7109-05/XS dated 18 September 1994.

E. Human Factors Assessment of Prototype Fragmentation Vests -Human Systems Report Contract No. W7701-3-7197-05/XSE dated 10 August 95.

F. Additional Human Factors Evaluation of the Proposed Generation III Prototype Fragmentation Vests – Humansystems Report Contract No. W7711-7-7429/04 dated 31 March 99.

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1.1 Background

In 1991, the Canadian Forces (CF) designed and built a fragmentation vest (Generation 0 or Gen 0) for the protection of our Land Force personnel against ballistic threats during military operations. Operational deficiencies with the fragmentation vest were reported shortly after introduction into service; these deficiencies included: excessive stiffness, degraded mobility, and incompatibility with helmets, weapon sights and in-service personal load carriage equipment.

In order to resolve the excessive stiffness problem with the Gen 0, the one-piece back panels were split horizontally and attached with elastic straps. While this modification (Generation 1 or Gen 1) was an improvement, many soldiers still did not feel capable of performing all their duties. In order to correct the vests operational deficiencies, a series of human factors (HF) investigations were undertaken (References B, C, D, E). The aim was to determine the scope of changes that could be accomplished in the Gen 0 and Gen 1, establish requirements for an optimal fragmentation vest design, and to define suitable designs and modifications to correct the limitations in the Gen 0 and Gen 1.

Three Canadian body armour manufacturers were approached to produce prototype fragmentation vests in the following configurations: side opening, front opening, and concealable. All vest designs included the capability for incorporating hard armour ceramic plates onto the front and back of the torso. A human factors expert paper-based evaluation of these prototypes was conducted in August 1994 (Reference D).

Based on this analysis, the CF down-selected to two vest designs for further feature refinement and subsequent Human Factors (HF) field trial evaluation of the two designs (Reference E).

A detailed one-week HF field trial was undertaken in May 1995 to evaluate the two fragmentation vest designs under scientifically controlled testing conditions. This HF trial included assessments of fit and adjustability, performance effectiveness in combat and battle task activities, thermal and physical demands, accessibility, maintainability, user acceptance, and clothing/equipment/vehicle compatibility, based on the HF criteria developed at Reference C. An additional one-month field evaluation was undertaken by the Land Force Trials and Evaluation Unit (LFTEU) Gagetown in April 1995 to evaluate the two fragmentation vest designs under appropriate battlefield conditions. The LFTEU trial involved approximately 100 soldiers operating as part of a combat team in all phases of war. Based on the recommendations from these trials, NDHQ selected a side-opening vest design as most suitable to pursue for the CF Fragmentation Vest Modification Programme.

Due to limitations with the earlier human factors and LFTEU trials, additional testing was conducted to evaluate the effects of adding hard armour. Based on the results of these trials, modifications to the vest were recommended and a modification data package for the G2122 Programme was developed.

The G2122 programme was subsequently cancelled and a decision was made to not salvage the soft armour from existing in-service stocks, but rather to transfer funds and authority to procure a new fragmentation vest as part of the Clothe the Soldier (CTS) Project. After the decision to utilize new armour was given, the Generation II vest was modified to a Generation III design in March 1998 incorporating the following changes:

- Using 17 layers of Twaron 2175 ballistic panels
- Raising the neckline to provide more coverage
- Raising the sides of the vest to provide more under the arm coverage
- Changing the shoulder closure from a double overlap to a large Velcro panel
- Providing more shoulder coverage through the use of a shoulder pad

The CTS project staff decided to evaluate two fragmentation vest prototypes incorporating the advantages afforded by new ballistic materials. One design was based upon the latest modification of the earlier Gen III Apr 98 design, and the other upon the "Danish" fragmentation vest design. The Generation III Apr 98 design was further refined (Gen III July 98) as follows:

- Using 17 layers of Twaron 8431 ballistic panels
- Permanently affixing the collar to the vest
- Changing the shoulder pad attachment system using a D ring at the shoulder apex
- Modification of the shoulder pad dot fastener locations
- Ensuring full side coverage

A five-day field trial (MOAT) was undertaken at CFB Petawawa over the period 28 September to 02 October 1998 (Reference F). Three fragmentation vest systems (Gen II, Gen III (July 98) and Danish) were evaluated by a total of 24 regular force male (n= 16) and female (n=8) participants. A balanced repeated measures comparison between vest conditions was performed. The human factors tests included assessments of fit and adjustability; accessibility; coverage; range of motion; weapon, clothing and equipment compatibility; weapon firing; performance of selected obstacle and combat tasks; battle tasks; comfort; and user acceptance. Data collection included questionnaires, focus groups, performance measures and human factors observer assessments. The modified Generation II vest –Gen III Apr 98 (Vest A) was generally rated higher than the Danish version (Vest B) or the original Generation II vest

(Vest C) across all evaluation metrics. Vest A was rated the most acceptable vest in the compatibility stands, combat task stands, firing stands, battle task stands and in the exit questionnaire. Vest B was generally rated the least acceptable vest across all evaluation metrics. Vest B was also rated as being unacceptable in many areas. While 74% of the subjects believed that Vest A was the best vest evaluated, 26% of the participants viewed Vest C as the best vest evaluated. None of the participants believed Vest B was acceptable for service issue. Minor modifications to Vest A would make it acceptable by 100% of the participants. Based on the results of this controlled HF Field trial, Vest A with modifications was recommended for future Canadian Forces (CF) procurement. Modifications and suggestions for further work were suggested. The modifications included:

- relieving the underarm cut by approximately 1.2 cm, and reducing the vest length by approximately 2.5 cm.
- adding a removable collar using snaps and Velcro
- changing the shoulder pad design so that the retaining strap is more sturdy
- providing a non slip shoulder and chest butt rest pad
- raising the location of the front hard armour plate pocket
- increasing the length of Velcro loop on front of vest

These changes to the Generation III vest were implemented (Gen III Feb 99) and a plan was developed to test the efficacy of the modifications in a confirmatory trial. An additional outcome of the HF Field Trial was the recommendation for validation of the proposed sizing system of the new vest followed by the development of a tariff for the Land Forces based on the proposed sizing system. A three day fit trial (MOAFT) was conducted with 198 subjects at CFB Petawawa during the period 7 to 11 June 1999. Subjects were required to pass through a number of separate fitting stands (fragmentation vest, rucksack, temperate combat boot, etc.) and anthropometry stands. Subjects were required to pass through up to four fitting and evaluation stands. The fitting, evaluation and anthropometry stands included:

- 2-D Scanning Anthropometry
- Traditional Anthropometry
- Fragmentation Vest Fitting
- Plate Interference

Unforeseen changes to the Generation III vest shell material negatively impacted user acceptance causing subjects to select bigger than anticipated vest sizes. The shell material was significantly stiffer than previously evaluated materials causing a number of problems. Fit limits to the existing sizing system were determined and a tariff for the Land Forces was developed. Based on the results of this fit trial, further modifications were recommended for the Generation III fragmentation vest (Gen III Feb 99). The modifications recommended included:

- relieving the underarm cut by approximately 1.2 cm
- relieving the neck cut by approximately 1.2 cm
- changing the shell material fabric

Prior to modifying the Generation III fragmentation vest design yet again, a confirmatory trial was recommended to investigate the efficacy of the earlier MOAT vest design changes and to see if a change in shell material could eliminate the latest design problems.

2. Aim

The aim of this field trial was to evaluate the human factors (HF) efficacy of design changes to the Generation III (July 98) fragmentation vest design as demonstrated in the Generation III (Feb 99) vest design (less CADPAT shell material).

3. Method

3.1 Overview

The following description provides a general overview of the trial method. Further details are provided in subsequent sections.

A one and one-half day trial was undertaken at CFB Petawawa over the period of 01 to 02 September 1999. Eleven regular force personnel were required to undertake a battery of human factors tests while wearing the two different fragmentation vest/fighting order conditions in a partially repeated measures design. During each test, the order of conditions was balanced amongst participants. Human factors tests included assessments of fit, performance of select obstacle and battle tasks, equipment, vehicle and clothing compatibility clash assessment. Data collection included questionnaires, focus groups, performance measures and HF observer assessments. Concurrent with the evaluation of the Generation III Fragmentation Vests, a separate trial examined the tactical assault vests. This load carriage system evaluation will be reported separately.

Due to the limited time available, limited number of subjects available and the limited number of Gen III (July 98) vest sizes produced, the evaluation was split into two blocks. The first block involved the evaluation of the earlier Gen III (July 98) against the Gen III (Aug 99) vests for regular length torsos. Since the Gen III (July 98) vests were only produced in a regular length, subjects that were short or tall could not be properly fitted into an earlier vest. A secondary aim of this trial was to insure that compatibility with the Clothe the Soldier (CTS) tactical assault vest (TAV) and the in-service 82-pattern webbing hadn't been compromised. Thus short and tall subjects were selected to evaluate the Gen III (Aug 99) vest between load carriage conditions. The evaluation of the Gen III (July 98) vests between load carriage conditions was accomplished during the extensive MOAT trial – Reference F.

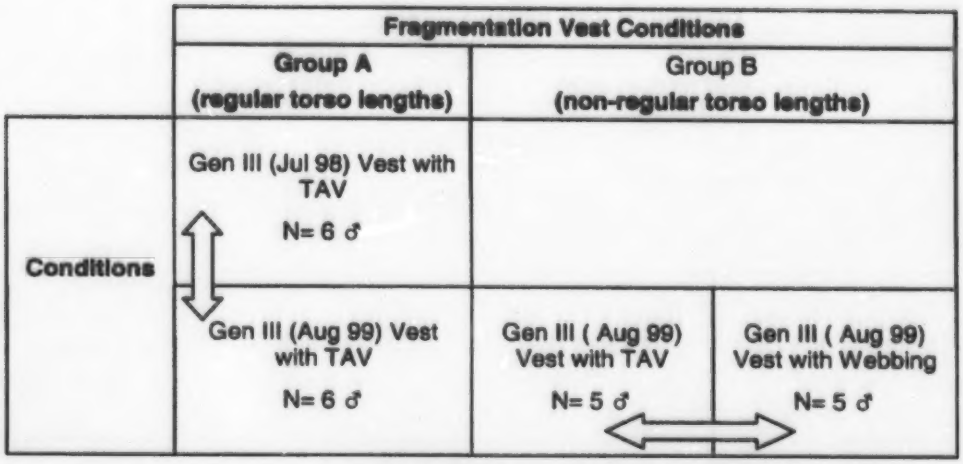
Fragmentation Vest Conditions
Group A
(regular torso lengths)
Group B
(non-regular torso lengths)
Conditions
Gen III (Jul 98) Vest with TAV
N= 6 ♂
Gen III (Aug 99) Vest with TAV
N= 6 ♂
Gen III (Aug 99) Vest with TAV
N= 5 ♂
Gen III (Aug 99) Vest with Webbing
N= 5 ♂

Table 1: Composite Vest Conditions

Use of similar test stands and questionnaires will allow meta-analysis (independent measures) between the earlier MOAT trial results for the Gen III (July 98) and the Gen III (Aug 99) if required.

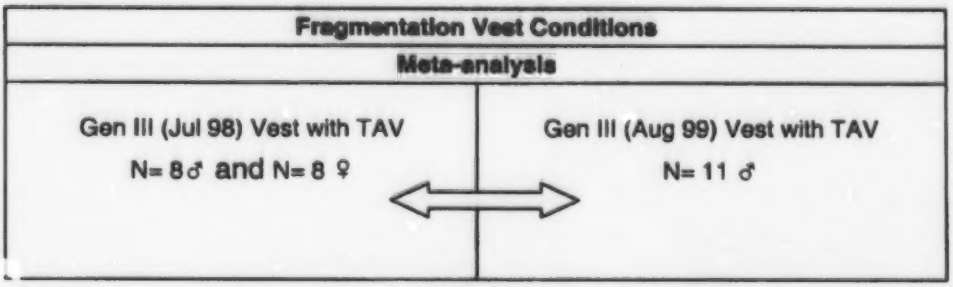

Table 2: Meta-analysis Conditions

3.2 Trial Conditions

The field trial included two fragmentation vest conditions: modified Gen III (Feb 99) Configuration (with new shell material) and an earlier Gen III (July 98) Configuration, two Fighting Order conditions: Tactical Assault Vest (TAV) and the in-service 82 pattern webbing, and two hard armour conditions (with and without armour plates). With a total of eight possible conditions and only two days of testing available, these conditions were rationalized to minimize testing time without compromising testing quality and validity. A full repeated measures protocol across all eight conditions was unachievable, given the number of human factors tests in the two days available. For this reason, priority was given to the fragmentation vest and fighting order conditions; the hard armour conditions were only tested selectively in the trial protocol. These condition considerations are discussed in more detail below.

3.2.1 Fragmentation Vest Conditions

Two fragmentation vest systems were evaluated in this trial, the modified Gen III (Feb 99) configuration and the earlier Gen III (July 98) design. Both vests have a side opening design providing full coverage to the torso. The fragmentation vests are composed of an outer protective shell and an inner ballistic fill assembly. The ballistic fill panels (Twaron 2175) are enclosed in water proof rip stop nylon bags. The vests are composed of the following components:

- Front shell panel
- Front ballistic fill panel
- Back shell panel
- Back ballistic fill panel
- Detachable shoulder pads
- Neck guard (detachable in the Gen III (Aug 99)

The Gen III (Feb 99) vest utilized in the fitting trial was modified to the Gen III (Aug 99) configuration as follows:

- Shell carriers were constructed with 1000 Denier cordura on the outside and 500 Denier cordura on the inside.
- New collars and shoulder pads were constructed with 1000 Denier cordura and new ballistic fill.
- Front plate pocket was raised approximately 1.3cm

Both the Gen III (July 98) and the Gen III (Aug 99) vests were very similar in appearance –see Figures 1A and 1B.

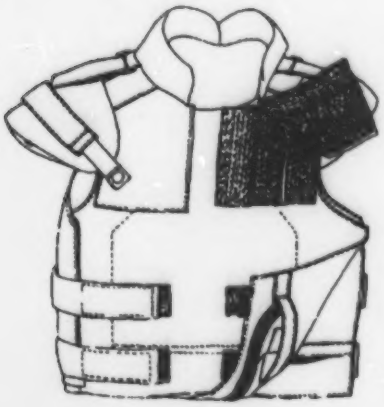

Figure 1A: Generation III (July 98) Vest

Figure 1B: Generation III (Aug 99) Vest

The Generation III (Aug 99) fragmentation vest design was produced in 12 vest sizes according to Table 3 below. The Generation III (July 98) fragmentation vest had been produced in only one torso size (regular) and three chest sizes (small, medium, and large).

Chest Size	Torso Length	Size Abbr.	Chest Circumference (mm)	Stature (mm)
Small	Short	SS	914.4 – 965.2	<1676.4
Small	Regular	RS	914.4 – 965.2	1676.4 – 1854.2
Small	Tall	TS	914.4 – 965.2	>1854.2
Medium	Short	SM	101.2 – 1066.8	<1676.4
Medium	Regular	RM	101.2 – 1066.8	1676.4 – 1854.2
Medium	Tall	TM	101.2 – 1066.8	>1854.2
Large	Short	SL	1117.6 – 1168.4	<1676.4
Large	Regular	RL	1117.6 – 1168.4	1676.4 – 1854.2
Large	Tall	TL	1117.6 – 1168.4	>1854.2
XLarge	Short	SXL	1219.2 – 1270	<1676.4
XLarge	Regular	RXL	1219.2 – 1270	1676.4 – 1854.2
XLarge	Tall	TXL	1219.2 – 1270	>1854.2

Table 3: Generation III (August 99) Garment Sizing

3.2.2 Fighting Order Conditions

Two load carriage systems were evaluated in this trial, the Cloth the Soldier (CTS) tactical assault vest (TAV) and the in-service 82-pattern webbing. The TAV is a prototype load bearing vest that is designed to be compatible with the new CTS small pack and rucksack. The vest has a number of fixed chest pockets and interchangeable side pockets allowing users to reconfigure their load carriage system as required. The 82-pattern webbing system is currently in service with the Land Forces. It consists primarily of an attachment belt, assorted pouches and supporting yoke assembly. The 82-pattern webbing systems were not found to be adequately compatible with the Generation 0 or Generation 1 fragmentation vest systems.

The two fighting order conditions –see Figures 2A and 2B, were standardized for load item configuration. This standardization ensured the bulk and weight implications of each individual load order were comparable, both between and within fighting order conditions, and equivalent across all participants. The standard "confirm trial" load order is detailed below in Table 4.

Load Order Item	Number
C7 Magazine (with 30 rds)	5 (one on the rifle)
1 Qt. Canteen (filled)	1
Bayonet	1
C9 Drum (200 rds) (for C9 gunner only)	1

Table 4: Fighting Order Load

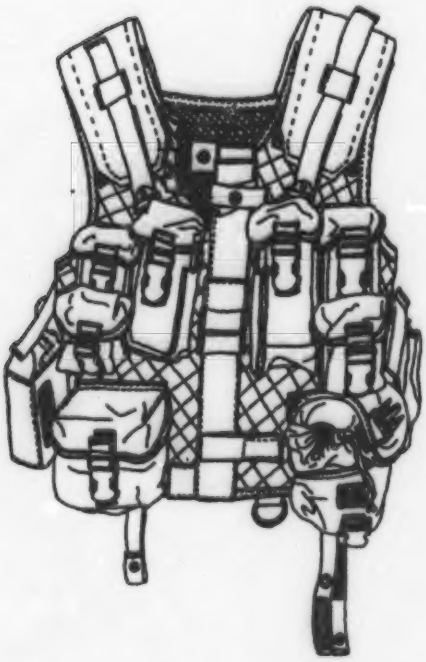

Figure 2A: Tactical Assault Vest (TAV)

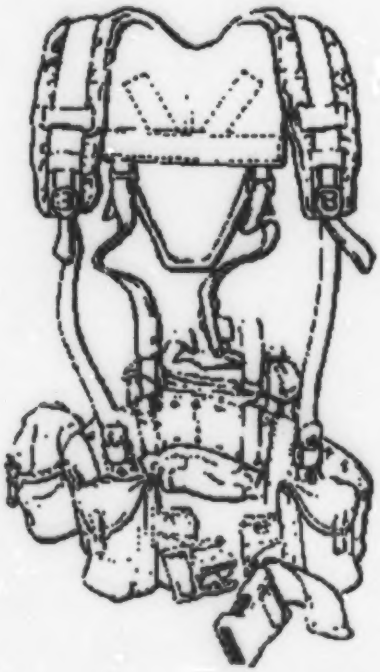

Figure 2B: 82-Pattern Webbing

3.2.3 Hard Armour Plate Conditions

Hard armour plates will increasingly become an integral up-armour capability of any future fragmentation vest in order to provide the soldier with additional protection against large fragments and direct fire threats. While this field trial was not convened to assess hard armour plates directly, the interaction between the in-service hard armour plates and the two fragmentation vest designs was evaluated. Therefore, the hard armour conditions were carefully allocated to various tests to represent the likely conditions of intended use and to emphasize plate interactions. These allocations are summarized in Table 5 below.

Human Factors Evaluation	Without Plates	With Plates
Compatibility Dry Stands	✔	✔
Obstacles	✔	
Fire & Movement	✔	✔
Civilian Vehicle Inspection	✔	✔

Table 5: Hard Armour Test Allocation

Select compatibility tests (C7A1 and C9A1) were undertaken to evaluate the plate implications on various weapons firing postures. Fire and movement tasks were performed with hard armour to assess the

implications on speed and ease of movement, tactical implications for use of ground and firing postures, and comfort effects. The suitability of hard armour with each vest design was also assessed for vehicle compatibility.

3.3 Participants

Eleven regular forces soldiers were selected from the previous fragmentation vest fitting trial. The participants selected for this trial were organized into two groups (e.g. A and B), each with five or six soldiers. Each group was balanced for chest size so that each group was as similar as possible (i.e. matched groups). A HF observer was assigned to work with each Section for the purposes of data collection and focus group discussions.

3.4 Weather conditions

The fragmentation vests were evaluated during relatively warm and clear conditions at CFB Petawawa (01 to 02 September 1999). Temperature highs were approximately 30°C for both days -see Table 6.

Date	Daytime High	Daily Low	Precipitation	Winds
01 September	30.0°C	7.0°C	0 mm	<10 Km/hr
02 September	29.5°C	10.5.0°C	0 mm	<10 Km/hr

Table 6: Trial Weather Conditions

3.5 Data Collection

Data collection focussed on the following HF criteria. Test content is described in more detail below. The order of fragmentation vest conditions was balanced.

1. Fit/Adjustability
2. Clothing/Equip. Compatibility
3. Vehicle Compatibility
4. Vehicle Inspection
5. Battle Task Performance
6. Thermal Load
7. Physical Comfort
8. User Acceptance
9. Features

Participants rated acceptability in all questionnaires using the following seven-point scale (Figure 3).

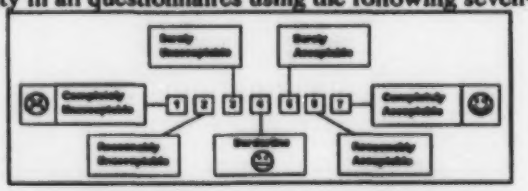

Figure 3: Standard Rating Scale

3.5.1 Anthropometry:

The subjects selected for this trial were participants in the previous fit trial. Each participant was measured for stature, weight, chest and waist (omphalion) circumference, shoulder length, acromial height, suprasternale height and iliocristale height.

3.5.2 Fit/Adjustability:

Participants were required to adjust vest sizing and perform donning/doffing trials. Upon completion of adjustment and fitting, participants completed a Fitting Questionnaire. HF observers evaluated the ease of fitting and the acceptability of the final fit.

3.5.3 Clothing/Equipment Compatibility:

Fragmentation vest/fighting order compatibility clash was identified and evaluated indoors at four static test stands. Participants were divided into smaller groups to perform the required drills and the HF observers collected compatibility measurement data and participant ratings. Participants were encouraged to adjust and configure their fragmentation vest and fighting order to the best of their ability to accommodate the test clothing and equipment prior to each test. Each participant was evaluated individually under the close observation of the HF observer – see Figures 4 and 5.

Figure 4: Subject Assessing the Gen III (Aug 99) Vest with the C7A1 Rifle in the Prone Position

The static test stands were comprised as follows:

- **Clothing:** IECS Jacket and IECS Parka.
- **Weapons:** C7A1 rifle, C9A1 LMG, M72 SRAAW, Carl Gustav.

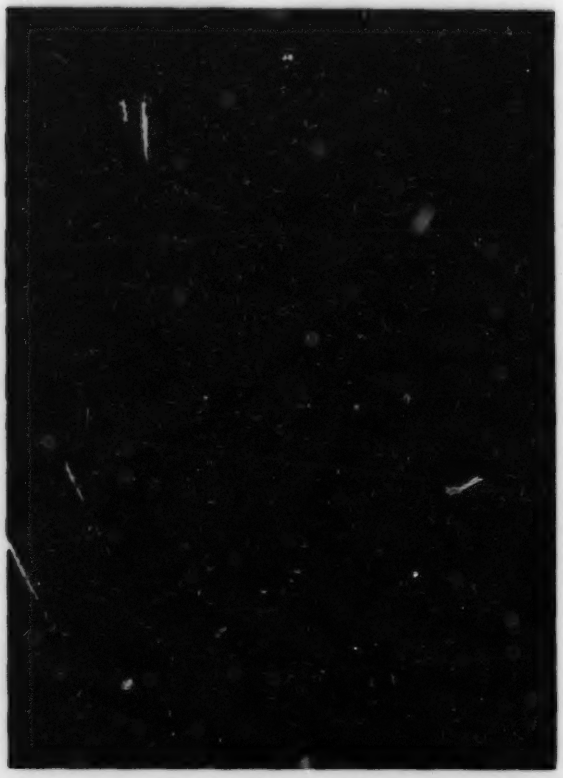

Figure 5: Subject Assessing Compatibility with the IECS Middle Layer Jacket

Participants were required to rate the compatibility of each fragmentation vest/fighting order combination and select plate conditions with each of the selected weapons, equipment, and clothing combinations at each test stand. HF observers measured clothing and equipment stand off and noted instances of compatibility clash and the accommodation required to perform each drill.

3.5.4 Vehicle Compatibility

All fragmentation vest/fighting order combinations and select hard armour conditions were evaluated for compatibility with two infantry vehicles: MLVW and Coyote – see Figure 6. Order of conditions was balanced. Specific evaluations included:

- **Access/Egress:** Participants were required to rate the ease of access and egress of vehicle hatches and doors. HFE observers evaluated soldiers entering and exiting vehicles for any postural, range of movement, and vehicle obstruction effects.

Figure 6: Subject Assessing Vehicle Compatibility in the Coyote

3.5.5 Combat Activity Performance

Fragmentation vest effects on the performance of military combat and peacekeeping tasks were evaluated for selected activities (obstacle course and civilian vehicle inspection).

3.5.5.1 Obstacle Course:

Thefollowing obstacles were undertaken consecutively as part of a single course. Subjective ratings by trial participants and performance timings were collected for each test. Participants performed these tests in their assigned fragmentation vest/fighting order conditions – see Figure 7. At the completion of the obstacle course for each condition, participants were required to complete a Task Questionnaire. For each obstacle, participants wore the New Soldier's Helmet and carried their C7A1.

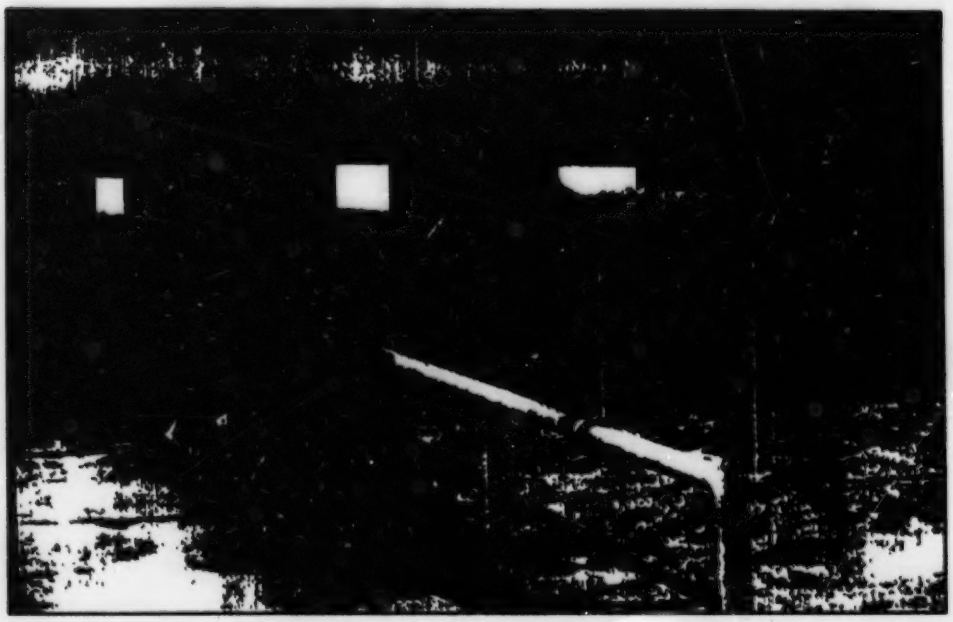

Figure 7: Subjects traversing the Over and Under Obstacle

The following obstacles were used:

- **100m Dash:** Sprint 100m.
- **Ladder Obstacle:** Ascend a 10m ladder, straddle and traverse the top bar, then descend the ladder to the ground.
- **Crawl:** Perform a Leopard crawl while traversing a 10m low wire obstacle.
- **Wall Obstacle:** Run 3m and climb (assisted) over a 2.4m high wall.
- **Pit Obstacle:** Run up a 2m ramp and jump down into a sandpit and perform a forward roll.
- **Over and Under Obstacle:** Climb over and under five successive horizontal poles mounted 0.5 and 1.0 meter from the ground.
- **Mouse Hole Obstacle:** Crawl through a square, concrete mouse hole shaft for 1m and climb over and under three successive horizontal poles mounted 0.5m, 1.0m, and 0.5m above the ground.

3.5.5.2 Civilian Vehicle Inspection:

This drill was designed to simulate the civilian vehicle inspection procedures required during peacekeeping roadblock checkpoints. Inspection activities included a standing inspection of the exterior bodywork, a kneeling inspection of a wheel well, a prone inspection of the car underside below the trunk, and stooped/crouched inspection of the passenger seat area – see Figure 8. Participants indicated a performance rating score for each vest condition.

Figure 8: Subject Performing the Vehicle Inspection Task

3.5.6 Fire and Movement Task Performance

Participants were required to engage in a Section attack simulation – see Figure 9. Participants rated their task/battle effectiveness in all conditions. HF observers evaluated the speed, agility, and postural effects of each condition.

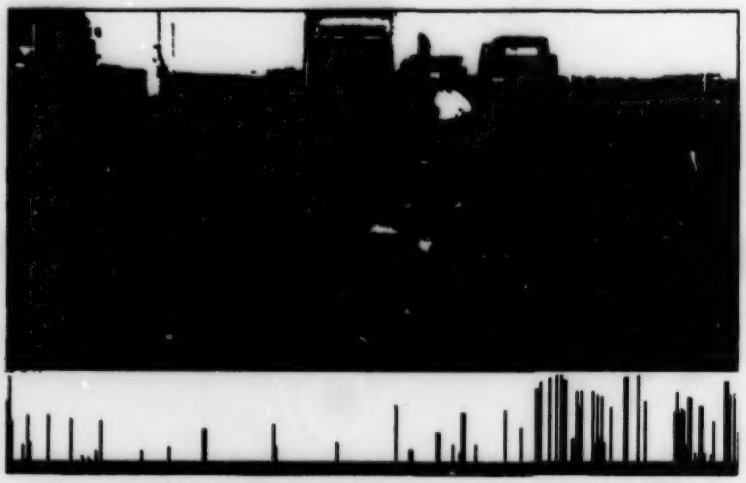

Figure 9: Subjects Participating in the Section Attack Task

3.5.7 Features

At the completion of the trial, participants were required to rate the suitability of select, prototype fragmentation vest design features: buckles, adjustments, coverage, collars, shoulder flaps, etc. These features were discussed in detail during the exit focus group to identify feature concerns and suggestions for improvement.

3.5.8 User Acceptance:

To assess user acceptance, participants were required to rate their overall acceptance of each vest, including their perceived level of protection, wearability, and the general appearance of the garment, using the exit questionnaire.

3.6 Trial Schedule

Table 7 outlines the one and a half-day trial schedule.

TRIAL WEEK: 01 Sep. - 02 Sep. 1999		
Time	**Wednesday 01 Sep**	**Thursday 02 Sep**
0745-0830	Initial Briefing	
0830-1015	Initial fitting C7A1 Rifle / C9 LMG Compatibility	Frag Confirm Exit Focus Group
1030-1230	M72/ Carl Gustav Compatibility IECS Compatibility Vehicle Inspection (Test Stands	TAV Confirm Exit Focus[1] Group
Lunch		
1300-1500	Fire and Movement	
1430-1730	Obstacle Course Vehicle Compatibility TAV – C9 Drum Compatibility[1]	

Table 7: Trial Schedule

Note: Separate evaluations of the TAV were also conducted during the fragmentation vest confirmatory trial.

4. Results

Trial results are detailed in the following Annexes and summarized below.

- Participant Characteristics:
- Fit and Adjustability:
- Compatibility:
- Combat Activities:
- Battle Tasks:
- Exit Focus Group:

4.1 Participant Characteristics

Subjects were pre-selected from the fitting trial to participate in the confirmatory trial. Subjects were selected from the 1st and 3rd Battalions the Royal Canadian Regiment to fit the Gen III (Aug 99) vest sizes available. Unfortunately, not all the sizes could be accommodated – see Table 8.

Torso Length	Chest Size	Size Abbr.	Chest Circumference (mm)	Stature (mm)	Number of subjects
Short	Small	SS	914.4 – 965.2	<1676.4	0
Regular	Small	RS	914.4 – 965.2	1676.4 – 1854.2	2
Tall	Small	ST	914.4 – 965.2	>1854.2	1
Short	Medium	SM	101.2 – 1066.8	<1676.4	1
Regular	Medium	RM	101.2 – 1066.8	1676.4 – 1854.2	2
Tall	Medium	RT	101.2 – 1066.8	>1854.2	1
Short	Large	SL	1117.6 – 1168.4	<1676.4	1
Regular	Large	RL	1117.6 – 1168.4	1676.4 – 1854.2	2
Tall	Large	TL	1117.6 – 1168.4	>1854.2	1
Short	XLarge	SXL	1219.2 – 1270	<1676.4	0
Regular	XLarge	RXL	1219.2 – 1270	1676.4 – 1854.2	0
Tall	XLarge	TXL	1219.2 – 1270	>1854.2	0

Table 8: Hypothetical Sizing System

The trial participants' anthropometric measurements (•) were compared to the 1997 DCIEM Land Forces Anthropometric Survey (•) (Reference F) to identify their general shape vis-à-vis the general Land Force. As can be seen in Figure 10, the subjects were not representative of the smaller chest sizes or the shorter Land Forces population.

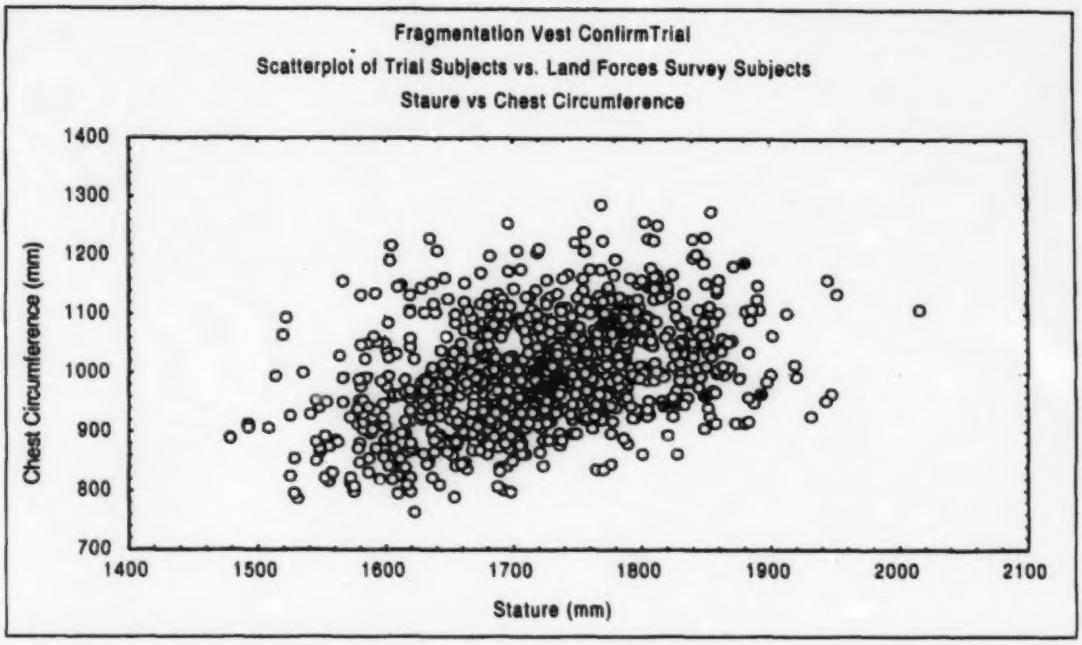

Figure 10: Scatterplot of Trial Subjects vs Land Forces Survey Subjects

4.2 Fit and Adjustment

After matching the subjects to the "best" fit achievable, the subjects were questioned on their perceptions of their initial fit. The subjects who were assigned a short or long Gen III (Aug 99) vest did not have a comparable torso length with the Gen III (July 98) vests. These subjects were assigned a regular length. Thus, some subjects would not achieve an acceptable fit with the three Gen III (July 98) vest sizes available. Overall, the subjects rated themselves as achieving a "Reasonably to Completely Acceptable" fit with the Gen III (Aug 99) fragmentation vest- see Figure 11.

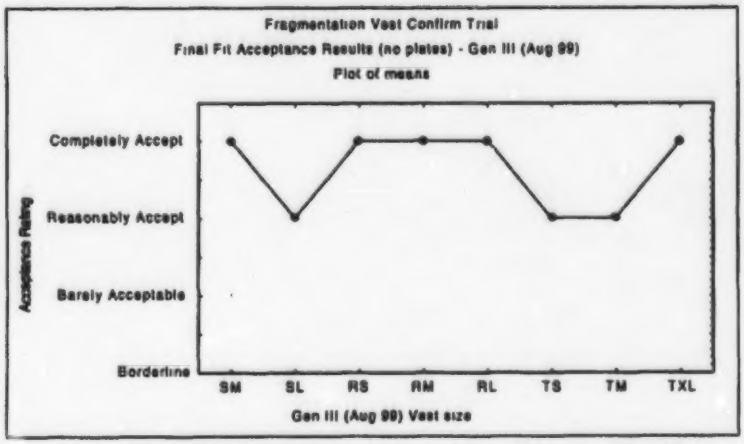

Figure 11: Final Fit Acceptance Rating – Gen III (Aug 99) (Mean)

Overall, the subjects rated themselves as achieving a "Borderline to Completely Acceptable" fit with the Gen III (July 98) fragmentation vest- see Figure 12.

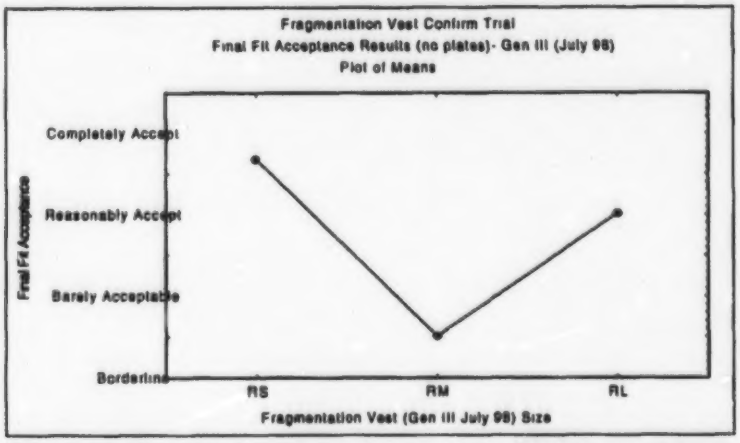

Figure 12: Final Fit Acceptance Rating – Gen III (July 98) (Mean)

Overall, all the participants achieved a better fit with the Gen III (Aug 99) vest than with the earlier Gen III (July 98) vest. While their was marginal difference in fit acceptance between the two vests without plates for the regular torso length subjects, the tall subjects rated the fit of the Gen III (July 98) as being substantially worse (Borderline).

The fit acceptance with plates did not differ significantly ($p<0.05$) than the fit acceptance without plates for both the Gen III (July 98) and the Gen III (Aug 99) fragmentation vests.

4.3 Weapon Compatibility

Compatibility with personal & crew served weapons, clothing and equipment was assessed with each vest condition. Additionally, compatibility with selected weapons and clothing items was also assessed by some participants wearing the Gen III (Aug 99) vest with plates.

4.3.1 C7A1 Rifle Compatibility

The Gen III (Aug 99) vest was found to be compatible with the C7 rifle both with and without plates. The subjects the compatibility as being " Reasonably Acceptable". When compared to the Gen III (July 98) vest, the subjects found no overall difference for C7A1 rifle compatibility. As expected compatibility for the vests without plates was higher than the C7A1 compatibility with plates – see Figure 13.

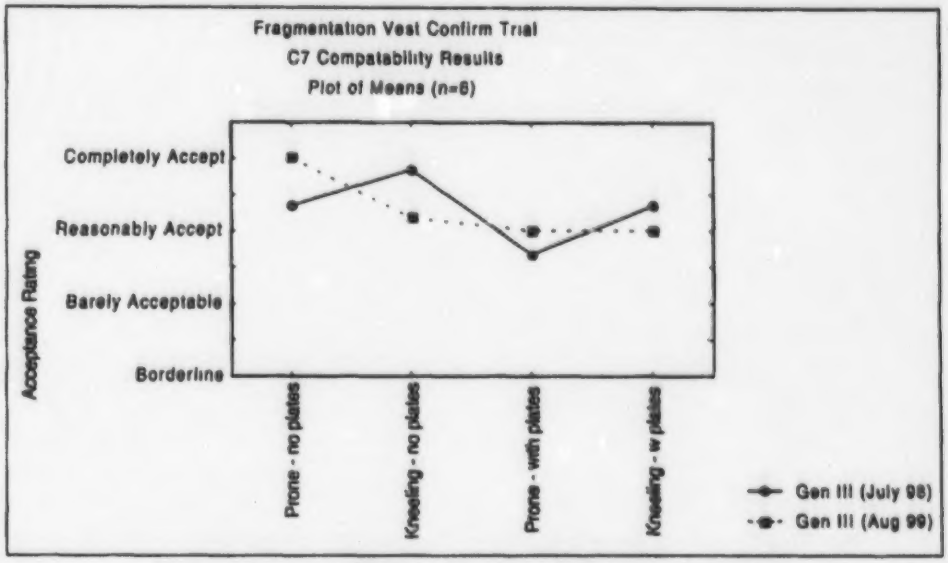

Figure 13: Compatibility with C7A1 Rifle versus Vest Type

The Gen III (Aug 99) vest was found to be compatible with the C7 rifle both with the Clothe the Soldier TAV and with the older 82-pattern webbing – see Figure 14. While most subjects rated the compatibility of the Gen III (Aug 99) vest with either load carriage condition as "reasonably to Completely Acceptable", one subject experienced difficulties shouldering his weapon with the TAV (rifle butt kept on slipping) and rated the compatibility as "Barely Acceptable".

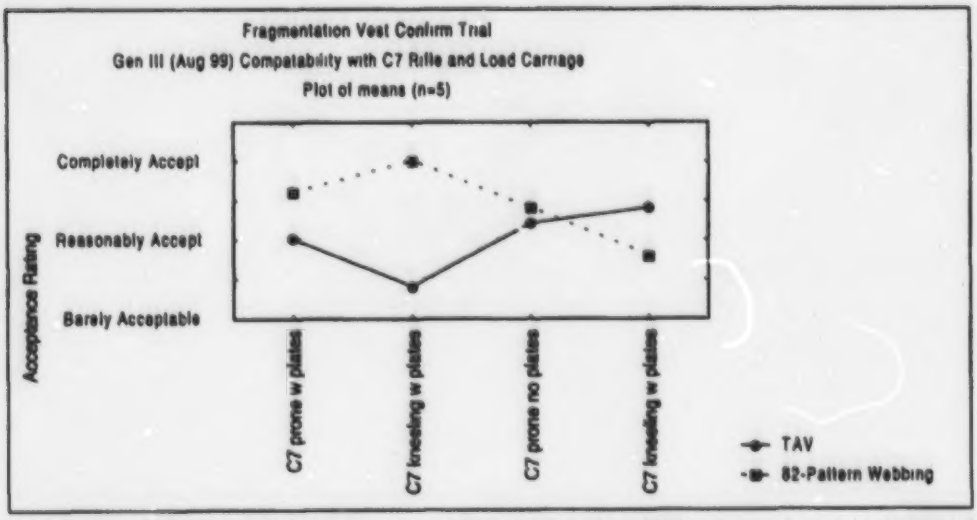

Figure 14: Gen III (Aug 99) Vest Compatibility with C7A1 Rifle versus Load Carriage Type

4.3.2 C9 Light Machine Gun Compatibility

The Gen III (Aug 99) vest was found to be compatible with the C9 rifle both with and without plates. The subjects rated the compatibility as being "Reasonably to Completely Acceptable". When compared to the Gen III (July 98) vest, the subjects found no overall difference for C9 LMG compatibility – see Figure 15.

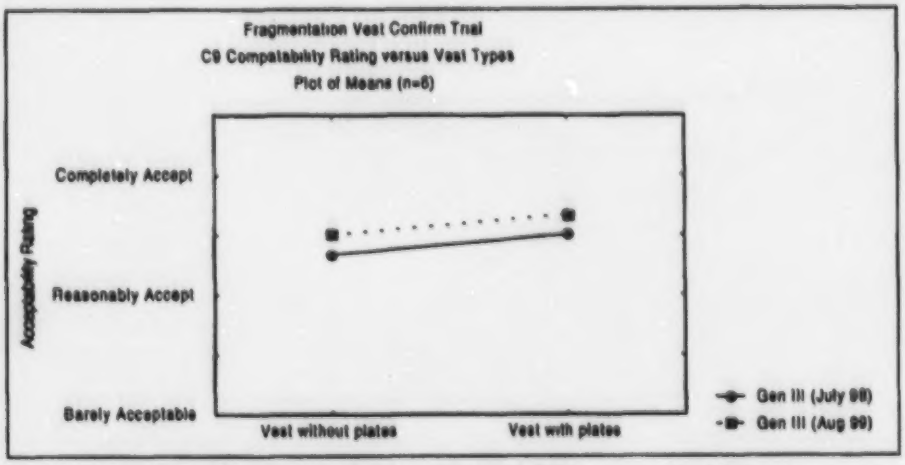

Figure 15: Compatibility with C9 LMG versus Vest Type

The Gen III (Aug 99) vest was found to be compatible with the C9 LMG both with the Clothe the Soldier TAV and with the older 82-pattern webbing. All the subjects rated the compatibility of the Gen III (Aug 99) vest with either load carriage condition with the C9 LMG as "Reasonably to Completely Acceptable" – see Figure 16.

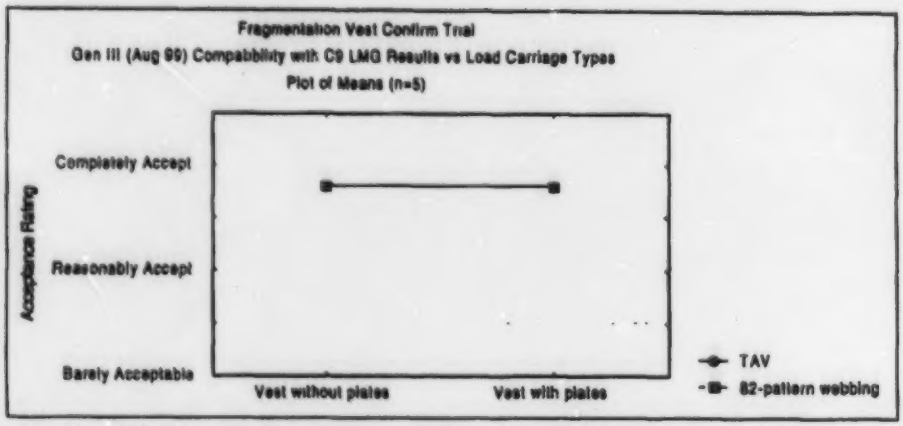

Figure 16: Gen III (Aug 99) Vest Compatibility with C9 LMG versus Load Carriage Type

4.3.3 Carl Gustav 84 mm Compatibility

The Gen III (Aug 99) vest was found to be compatible with the 84mm rocket launcher at both the number one and number two positions. The subjects rated the compatibility as being "Reasonably to Completely Acceptable". When compared to the Gen III (July 98) vest, the subjects found no overall difference for Carl Gustav compatibility – see Figure 17.

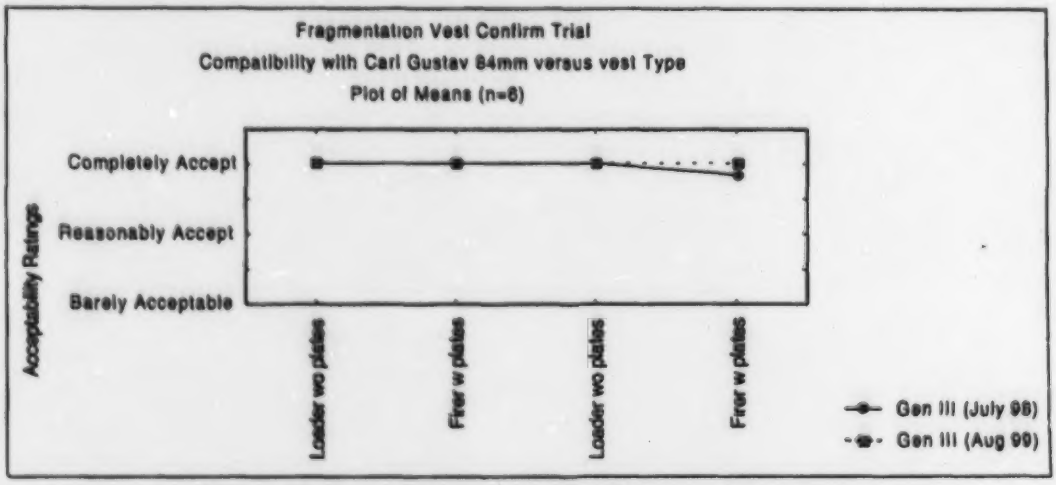

Figure 17: Compatibility with C9 LMG versus Vest Type

The Gen III (Aug 99) vest was found to be compatible with the Carl Gustav for either system position both with the Clothe the Soldier TAV and with the older 82-pattern webbing. The subjects rated the compatibility of the Gen III (Aug 99) vest with either load carriage condition with the Carl Gustav as "Reasonably to Completely Acceptable" both with and without plates – see Figure 18.

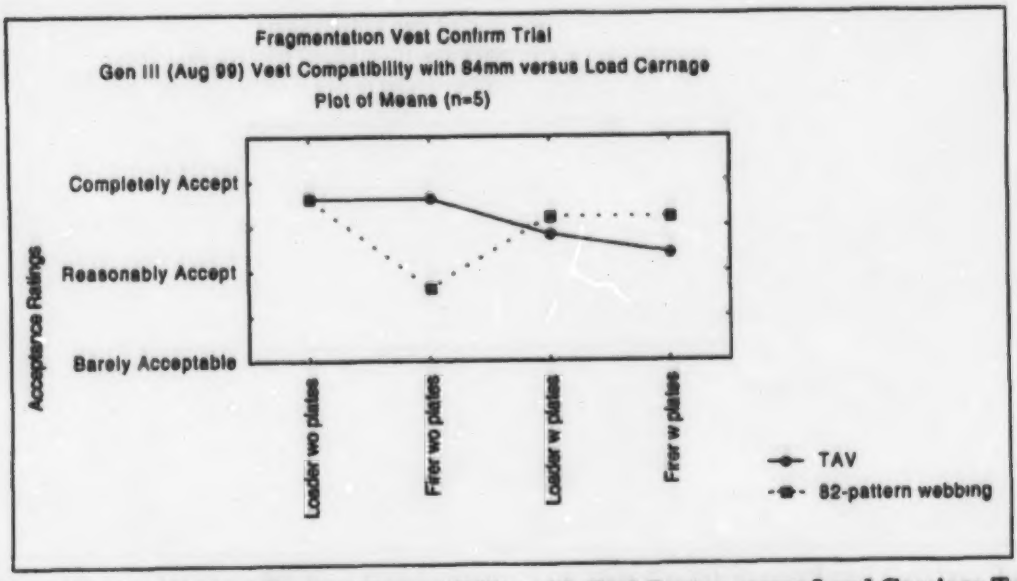

Figure 18: Gen III (Aug 99) Vest Compatibility with Carl Gustav versus Load Carriage Type

4.3.4 M72 SHRAAW (L) Compatibility

The Gen III (Aug 99) vest was found to be compatible with the M72 rocket launcher. The subjects rated the compatibility both with and without plates as being "Reasonably to Completely Acceptable" for both the Gen III (July 98) and Gen III (Aug 99) vests – see Figure 19.

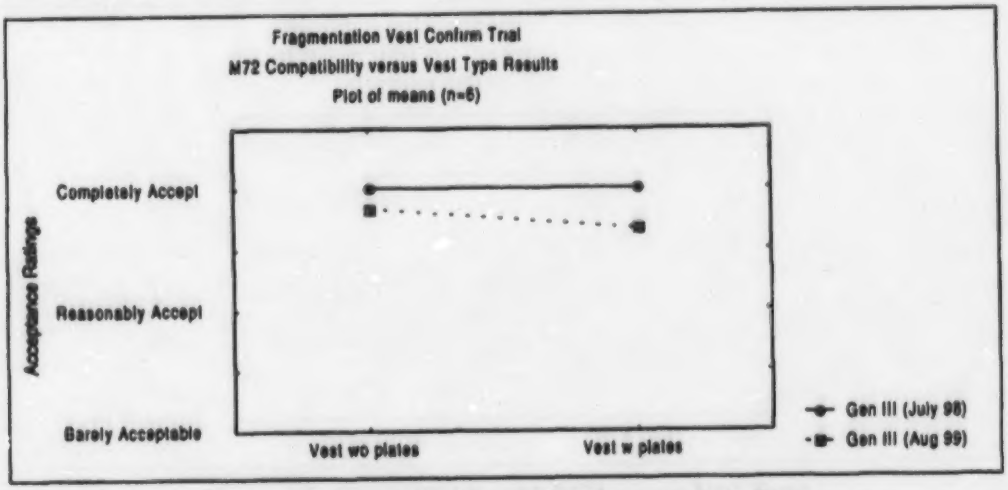

Figure 19: Compatibility with M72 versus Vest Type

The Gen III (Aug 99) vest was found to be compatible with the M72 both with the Clothe the Soldier TAV and with the older 82-pattern webbing. The subjects rated the compatibility of the Gen III (Aug 99)

vest with either load carriage condition with the M72 as "Completely Acceptable" both with and without plates – see Figure 20

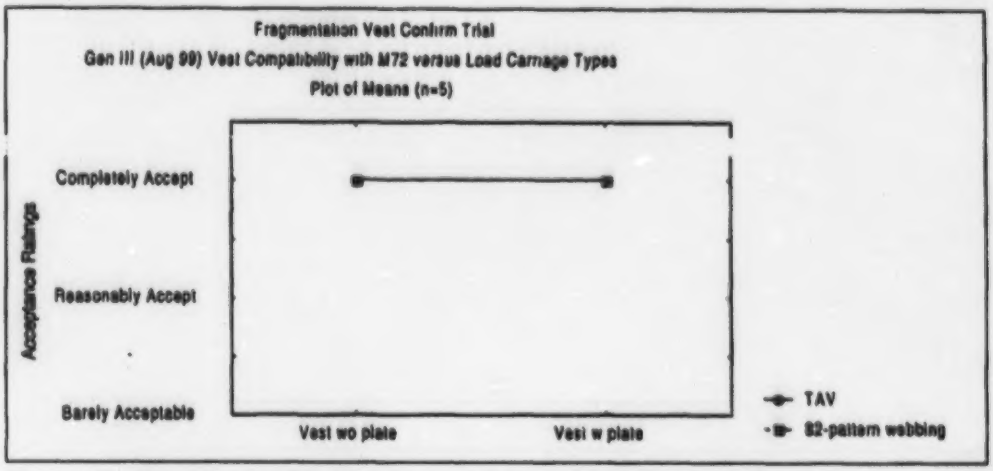

Figure 20: Gen III (Aug 99) Vest Compatibility with M72 versus Load Carriage Type

4.3.5 Clothing and Equipment

Compatibility of the subjects with the IECS middle layer jacket and parka was assessed with the Gen III (Aug 99) fragmentation vest. The assessments were made while the subjects were not wearing any load carriage systems. Compatibility with the middle layer jacket was also assessed with participants wearing vests with plates. Subjects rated the compatibility of the Gen III (Aug 99) vests with the IECS clothing systems as being "Reasonably to Completely Acceptable" – see Figure 21

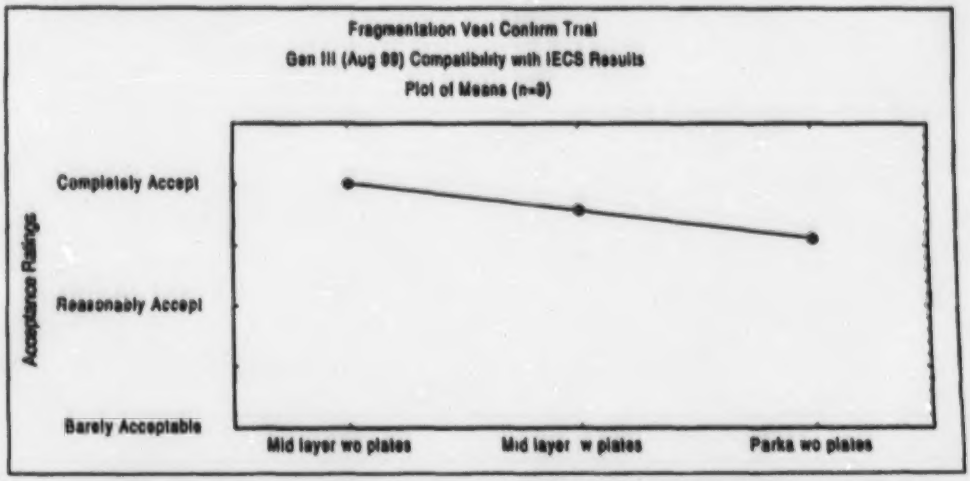

Figure 21: Gen III (Aug 99) Vest Compatibility with IECS Jacket and Parka

4.3.6 Vehicles

The Gen III (Aug 99) vest was found to be compatible with the MLVW and Coyote armoured vehicle. The subjects rated the compatibility both with and without plates as being "Reasonably to Completely Acceptable" for both the Gen III (July 98) and Gen III (Aug 99) vests – see Figure 22.

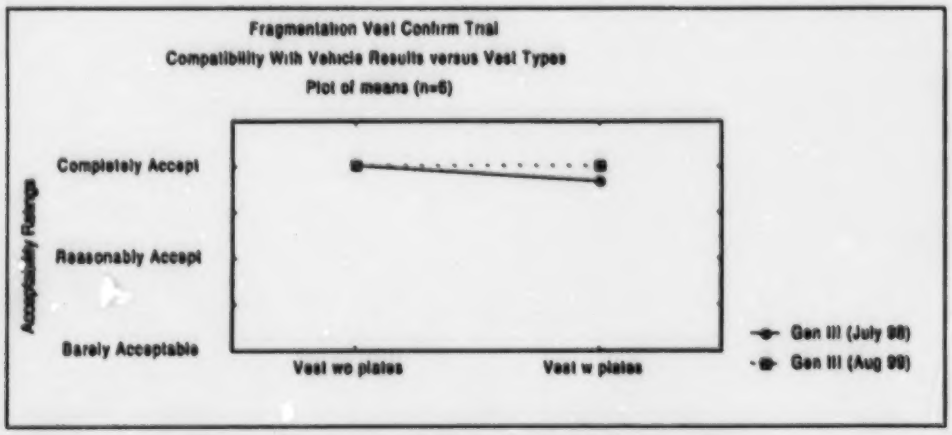

Figure 22: Compatibility with Vehicles Vest Type

Compatibility of the subjects with an MLVW truck and a Coyote armoured vehicle was assessed with the Gen III (Aug 99) fragmentation vest. The assessments were made while the subjects were wearing the two load carriage systems. While compatibility with the TAV was assessed as being "Reasonably Acceptable" for the Gen III (Aug 99) vests with and without plates, compatibility with the 82-pattern webbing was assessed as being unacceptable – see Figure 23. Although the subjects greatly preferred wearing the TAV, they stated that they would not normally wear webbing while inside a vehicle as was tested.

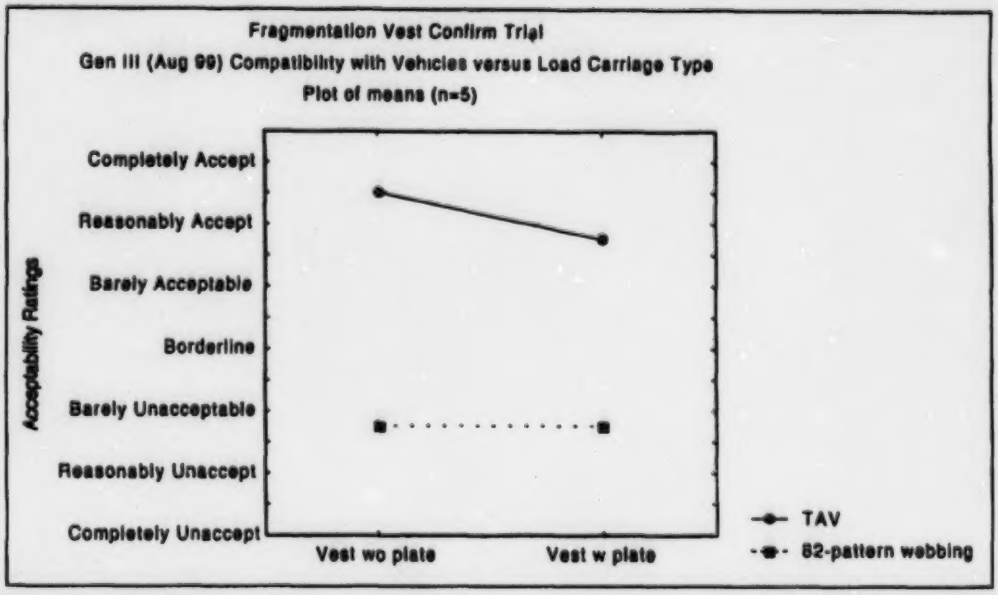

Figure 23: Gen III (Aug 99) Vest Compatibility with Vehicles versus Load Carriage Types

Post-hoc analysis revealed that vehicle compatibility acceptance with the Gen III (Aug 99) vest with a TAV was rated significantly ($p<0.05$) better than the Gen III (Aug 99) with 82-pattern webbing.

4.4 Combat Activities

Combat activity performance was evaluated with the vest and load carriage conditions during obstacle course and vehicle inspection stands.

4.4.1 Obstacle Course

Participants were required to complete a series of CF standard obstacles in rapid succession as a member of a section. Upon completion of each vest condition participants were required to complete an Obstacle Task Questionnaire. All participants traversed the obstacle course in combat clothing at first to practice individual obstacle crossing and to establish a baseline level of performance to evaluate the effects of fragmentation vest or load condition.

The Obstacle Course Task Questionnaire Results (Mean Ratings) are summarized below in Figures 24 and 25. Overall, the Gen III (July 98) and Gen III (Aug 99) vests were rated as being "Reasonably Acceptable" for the obstacle course tasks.

Post-hoc analysis did not reveal any significant ($p<0.05$) differences between the Gen III (July 98) and Gen III (Aug 99) vest acceptability scores.

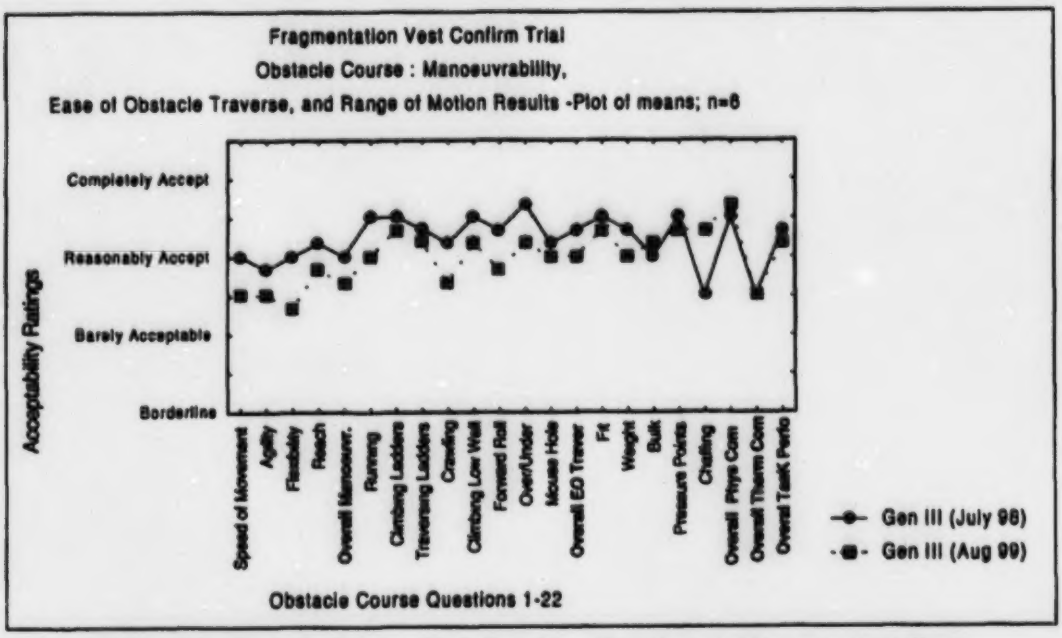

Figure 24: Obstacle Course Task Results – Questions 1-22 versus Vest Type

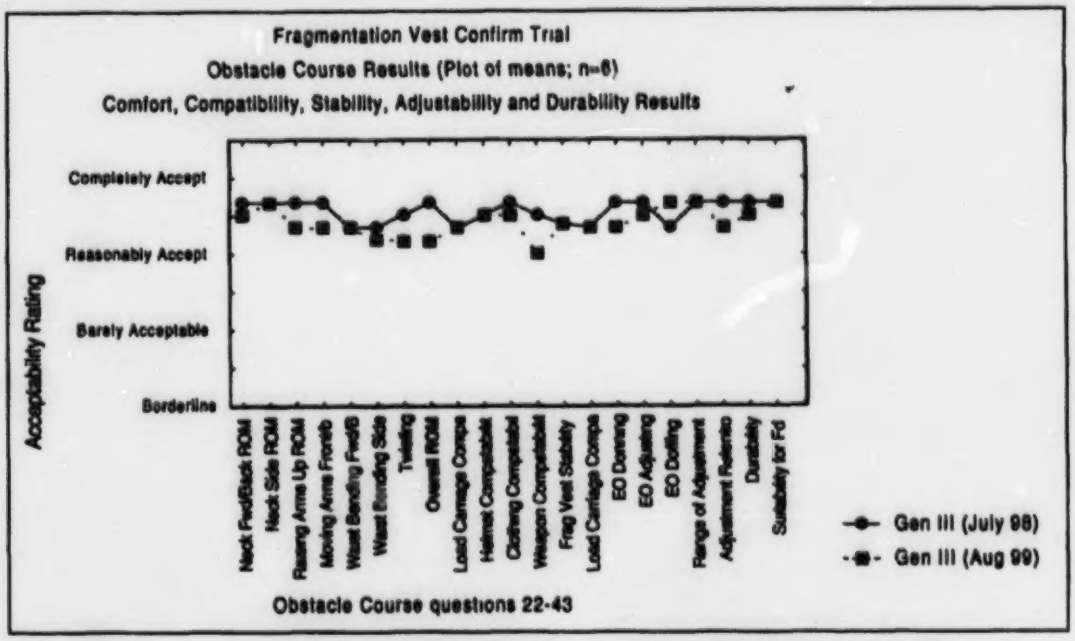

Figure 25: Obstacle Course Task Results – Questions 23-43 versus Vest Type

Compatibility of the subjects with the obstacle course task was assessed with the Gen III (Aug 99) fragmentation vest. The assessments were made while the subjects were wearing the two load carriage systems. The Gen III (Aug 99) vest was rated as being acceptable for all obstacle course task criteria except for thermal comfort. The subjects do not normally wear fragmentation vests while on the obstacle course. Thus their physical exertion coupled to the high ambient temperature created thermal strain amongst the participants. It is suggested that this is a reality for any conventional vest design. Overall the Gen III (Aug 99) vest was found to be compatible with the TAV and the 82-pattern webbing while performing obstacle traverse. Select obstacle course task questionnaire results are illustrated below in Figures 26 and 27.

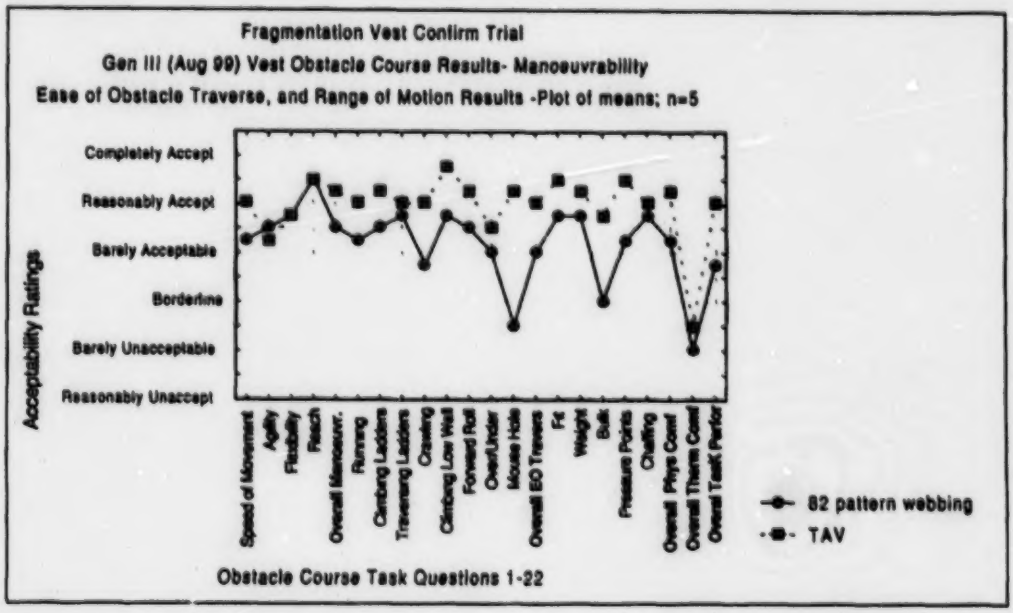

Figure 26: Gen III (Aug 99) Vest Compatibility with Obstacle Course Task (Questions 1-22) versus Load Carriage Types

Post-hoc analysis did not reveal any significant ($p<0.05$) differences between for the Gen III (Aug 99) load carriage condition acceptability scores.

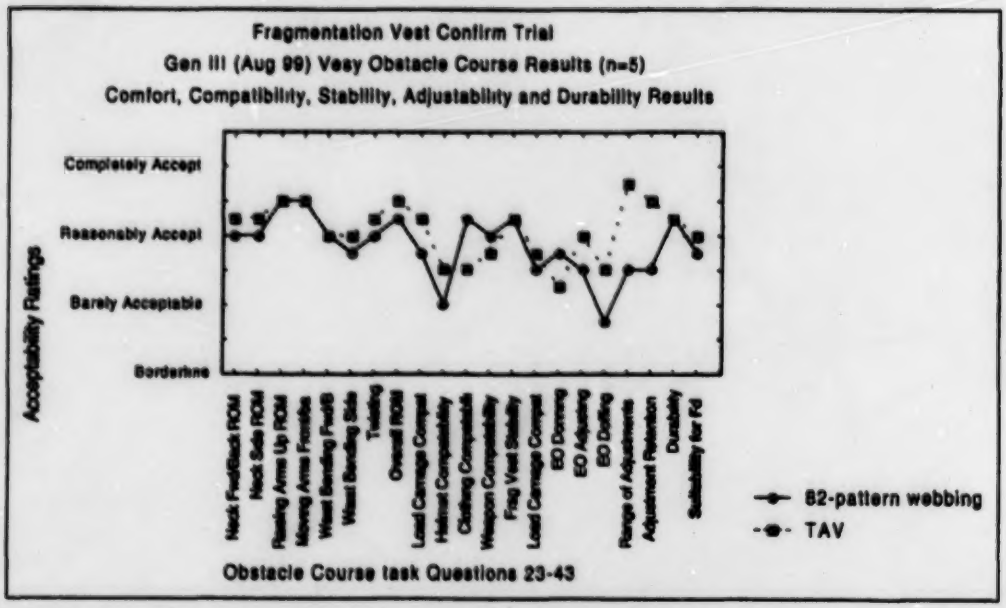

Figure 27: Gen III (Aug 99) Vest Compatibility with Obstacle Course Task (Questions 23-43) versus Load Carriage Types

4.4.2 Vehicle Inspection

Participants were required to perform a simulated vehicle inspection. This drill was designed to simulate the civilian vehicle inspection procedures required during peacekeeping roadblock checkpoints. Inspection activities will include a standing inspection of the exterior bodywork, kneeling inspection of a wheel well, prone inspection of the car underside below the trunk, and stooped/crouched inspection of the passenger seat area. For all fragmentation vest/fighting order conditions, participants were required to rate the ease of vehicle inspection activities.

The Vehicle Inspection Task Results (Mean Ratings) are illustrated below in Figures 28 and 29. Overall, the Gen III (July 98) and Gen III (Aug 99) vests were rated as being "Reasonably to Completely Acceptable" for vehicle inspection tasks.

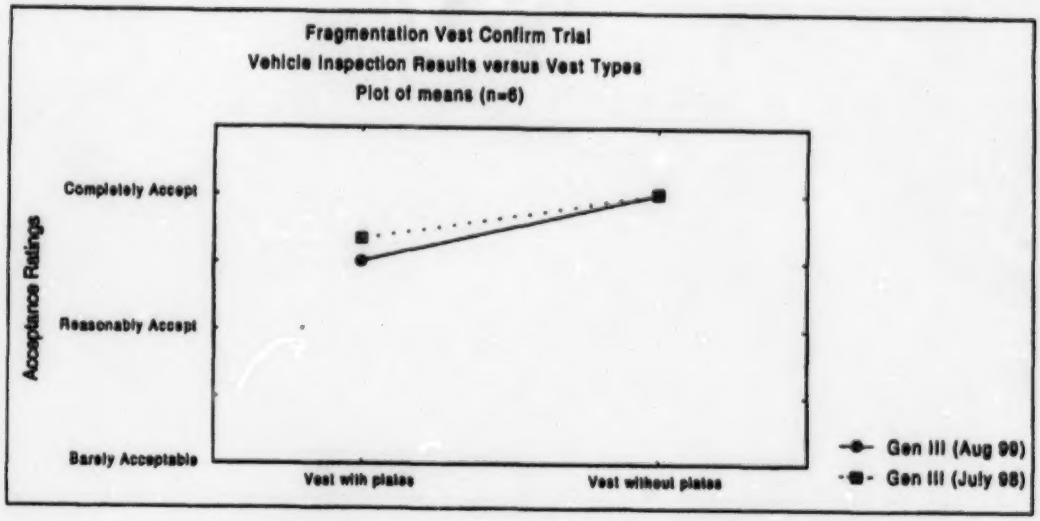

Figure 28: Vehicle Inspection Task Results –versus Vest Type

Compatibility of the subjects with vehicle inspection task was assessed with the Gen III (Aug 99) fragmentation vest. The assessments were made while the subjects were wearing the two load carriage systems. The Gen III (Aug 99) vest was rated as being acceptable both with and without plates for both load carriage systems – see Figure 28. As expected compatibility without plates was rated higher than vests with plates. Subjects preferred wearing the TAV while conducting vehicle inspection tasks. The design of the TAV allowed them to crawl under the vehicle and crawl inside the vehicle easier.

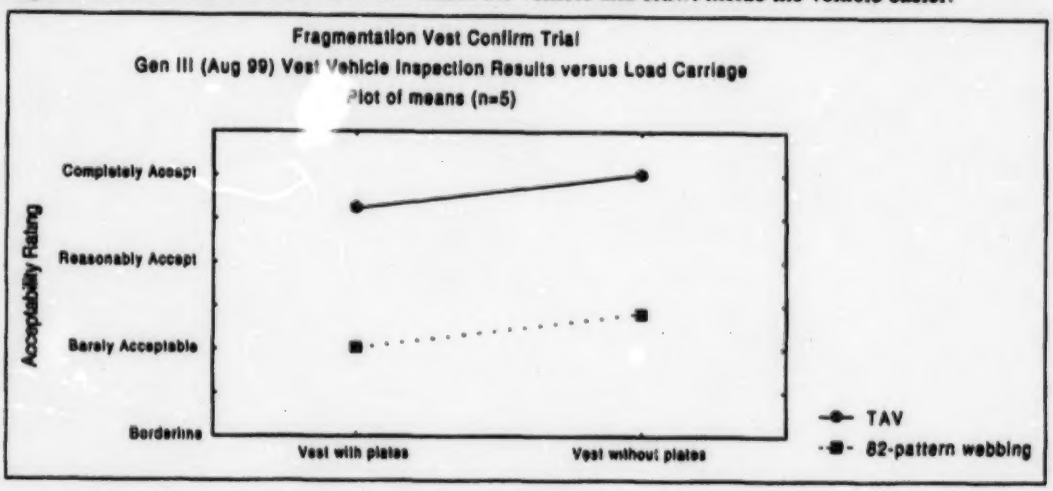

Figure 29: Gen III (Aug 99) Vest Compatibility with Vehicle Inspection Task versus Load Carriage Types

Post-hoc analysis revealed that vehicle inspection task compatibility acceptance with the Gen III (Aug 99) vest with a TAV was rated significantly ($p<0.05$) better than the Gen III (Aug 99) with 82-pattern webbing.

4.5 Battle Tasks

Participants performed section fire and movement to evaluate the effect of the different vests on perceived fighting effectiveness during realistic simulations of combat operations. Participants were combined into one augmented section. Previously, all the participants had observed a fire and movement drill and then had practised the tactical drills. The battle tasks were performed in a non-tactical setting beside 3RCR lines.

The drill involved the platoon advancing along a field where upon they were engaged by a separate enemy force. Upon contact the section broke into group fire and movement and cleared the forward enemy position. Task compatibility results for each vest condition are described below in Figures 30 and 31.

The Gen III (July 98) and the Gen III (Aug 99) vests received a mean overall rating of "Reasonably to Completely Acceptable" rating for the Fire and Movement task.

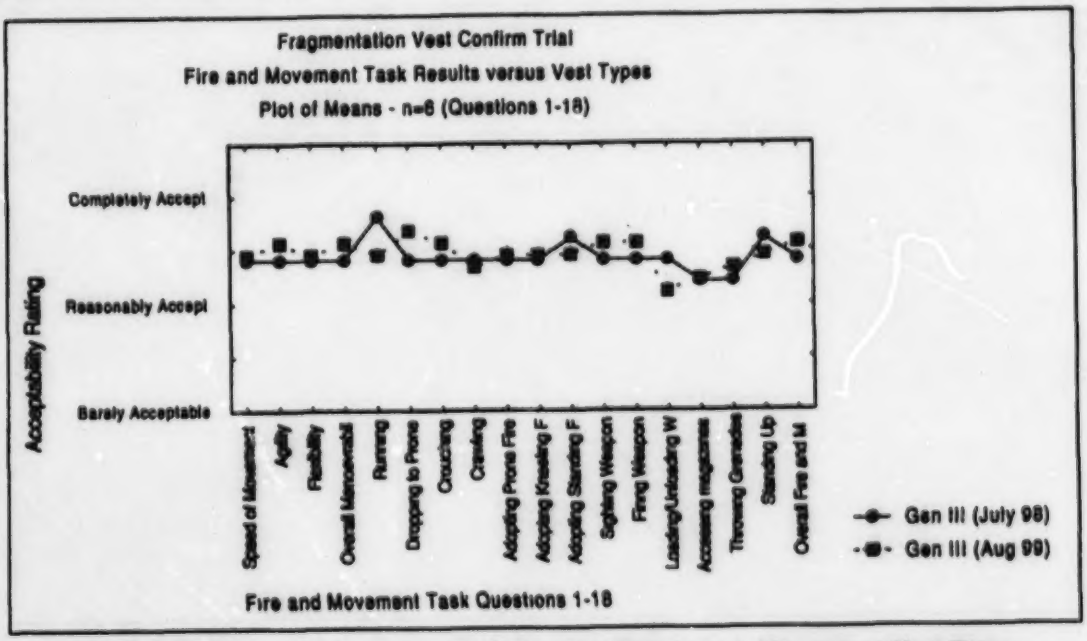

Figure 30: Fire and Movement Task Results (Questions 1-18) –versus Vest Type

Post-hoc analysis did not reveal any significant ($p<0.05$) differences between the Gen III (July 98) and Gen III (Aug 99) vest acceptability scores for the Fire and Movement task.

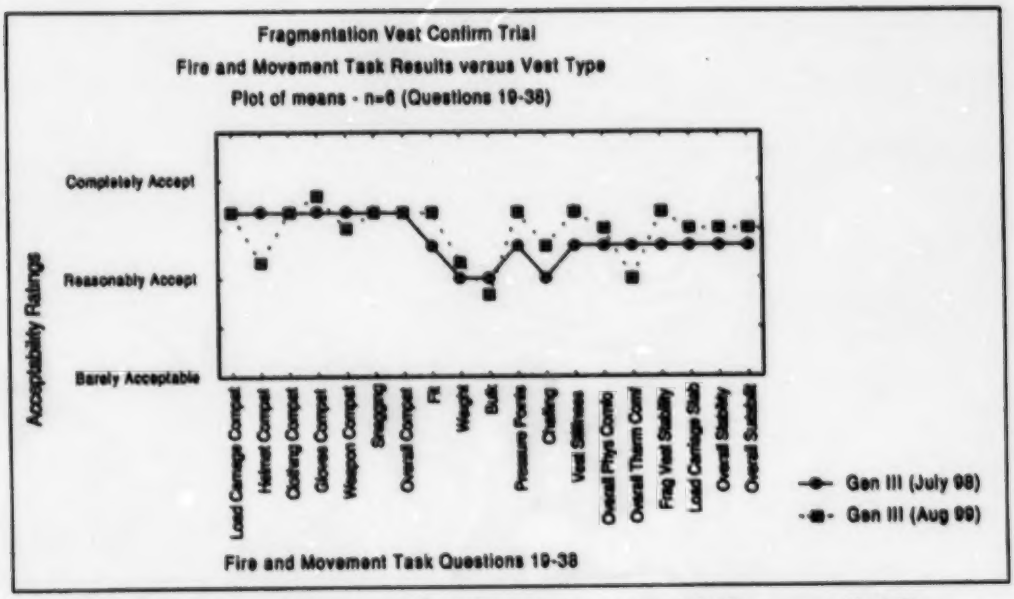

Figure 31: Fire and Movement Task Results (Questions 19-38) –versus Vest Type

Compatibility of the subjects with the Fire and Movement task was assessed with the Gen III (Aug 99) fragmentation vest for two load carriage conditions. Fire and movement assessments were made while the subjects were wearing the two load carriage systems. The Gen III (Aug 99) vest was rated as being acceptable both the TAV and 82-pattern webbing load carriage systems – see Figures 32 and 33. As expected, subjects preferred wearing the TAV while conducting the fire and movement tasks.

The Gen III (July 98) vest with the TAV received a mean overall rating of "Reasonably to Completely Acceptable" rating for the Fire and Movement task. Conversely, the Gen III (Aug 99) vest with the 82-pattern webbing received a "Barely to Reasonably Acceptable" rating while performing the fire and movement tasks.

A post-hoc analysis revealed a significant difference between acceptance of the Gen III (Aug 99) vest for the two load carriage conditions. The TAV condition was rated significantly more acceptable ($p<0.05$) than the 82-pattern webbing condition.

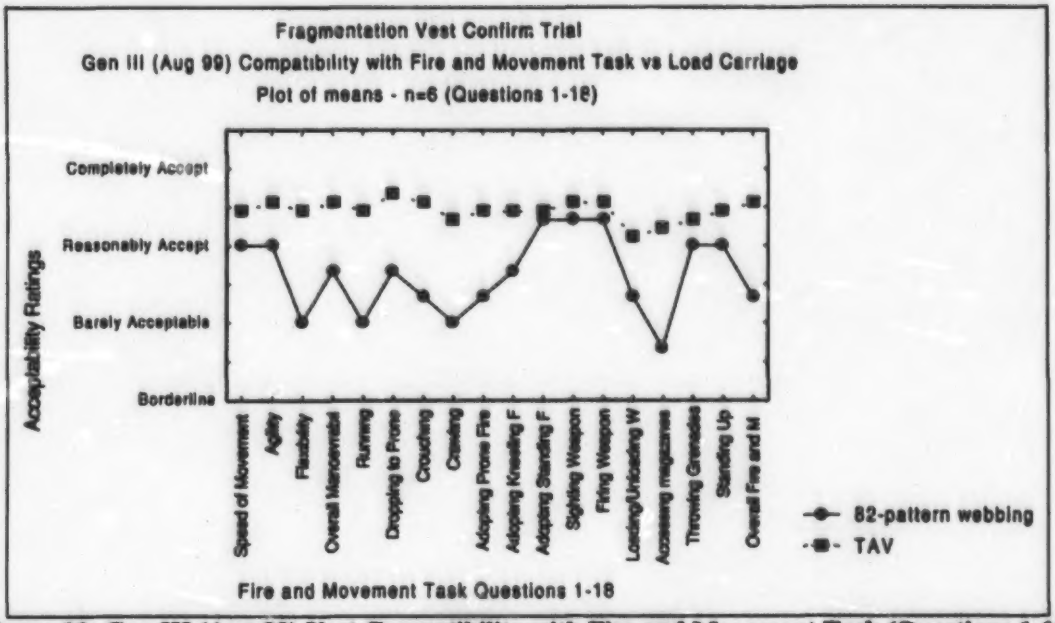

Figure 32: Gen III (Aug 99) Vest Compatibility with Fire and Movement Task (Questions 1-18) versus Load Carriage Types

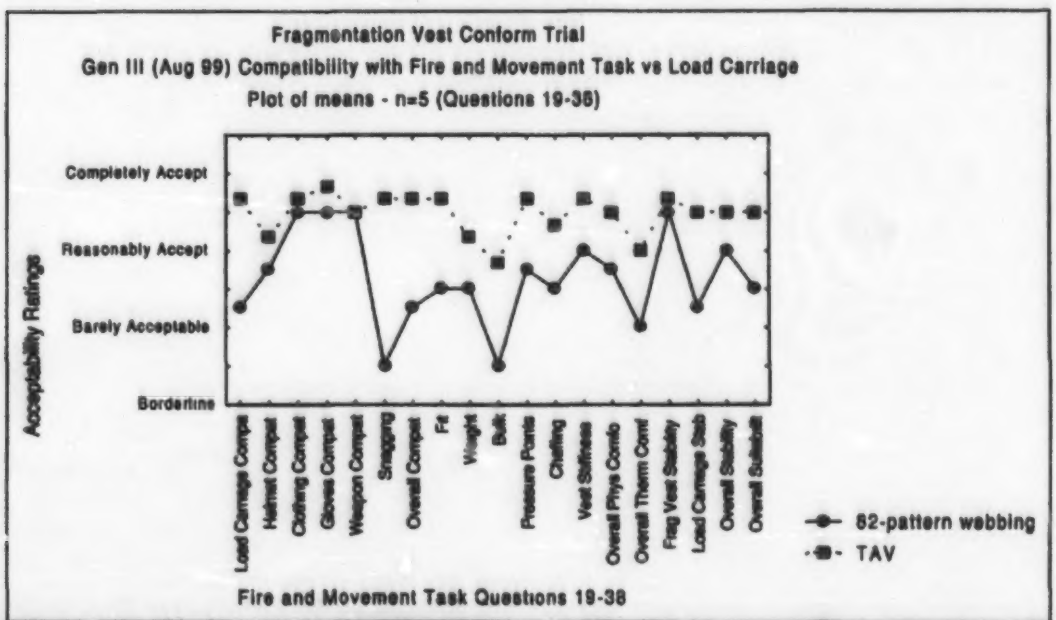

Figure 33: Gen III (Aug 99) Vest Compatibility with Fire and Movement Task (Questions 19-38) versus Load Carriage Types

4.6 Exit Focus Group

A focus group was held at the completion of the trial to allow subjects to perform a direct comparison of either the vest types or load carriage conditions, rate specific vest features, rate criteria of importance and as a group, discuss their reasons for specific vest preferences and suggestions for future improvements. Participants were issued the following Questionnaires:

- Features Questionnaire (for each vest)
- Criteria of Importance Questionnaire
- Exit Questionnaire (Without Plates)
- Exit Questionnaire (With Plates)

Following the completion of the questionnaire battery, a brief focus group discussion was held to determine which vest was preferred by the participants for the exit questionnaire human factors (HF) criteria. Finally suggestions on improving the recommended vest design were discussed.

4.6.1 Features Questionnaire

Participants were asked to rate the functionality and durability of the individual design features incorporated in the two different vest designs. Results of the participant ratings are described below for each vest.

4.6.1.1 Gen III (July 98) Feature Questionnaire Results

Descriptive statistics for ratings of feature durability and functionality for the Gen III (July 98) vest are provided below in Tables 1 and 2. Note n= 5 for the evaluation of the Gen III (July 98) vest.

1. Collar	5.6	0.9	6.0	1.2
2. Shoulder Pad	6.0	0.7	5.8	0.4
3. Shoulder Pad Strap	5.8	1.1	5.8	1.1
4. Shoulder Pad Elastic	6.4	0.5	5.8	0.4
5. Shoulder Pad Snap	5.6	0.9	5.4	0.9
6. Shoulder Adjustment	7.0	0.0	6.6	0.5
7. Shoulder Adjustment Velcro	7.0	0.0	6.8	0.4
8. Front Plate Pocket	6.8	0.4	6.8	0.4
9. Front Plate Pocket Velcro	6.8	0.4	6.8	0.4
10. Side Adjustment	6.8	0.4	6.8	0.4
11. Side Adjustment Velcro	7.0	0.0	6.8	0.4
12. Panel Pocket Velcro	7.0	0.0	6.8	0.4
13. Shell Material	7.0	0.0	7.0	0.0

Table 8: Gen III (July 98) Vest Features (Front)

1. Shoulder Pad Panel Pocket Velcro	6.4	0.9	6.4	0.8
2. Shoulder Pad Snap (Back)	5.6	0.4	5.2	0.4
3. Rear Plate Pocket	6.8	0.0	6.8	0.4
4. Rear Plate Pocket Velcro	7.0	0.5	6.8	0.4
5. Side Elastic Limit Strap	6.6	0.5	6.4	0.9
6. Side Strap Pull Tab	6.6	0.5	6.6	0.5

Table 9: Gen III (July 98) Vest Features (Back)

The durability and functionality of the features incorporated in the Gen III (July 98) vest were all rated as being acceptable.

4.6.1.2 Gen III (Aug 99) Feature Questionnaire Results

Descriptive statistics for ratings of feature durability and functionality for the Gen III (Aug 99) vest are provided below in Tables 3 and 4.

1. Collar	6.2	0.8	6.0	0.7
2. Shoulder Pad	5.7	0.7	6.2	0.4
3. Butt Rest Non-slip Pad	6.8	0.4	6.6	0.7
4. Shoulder Pad Elastic	6.1	0.6	5.6	0.8
5. Shoulder Pad Snap	6.5	0.5	6.1	1.0
6. Shoulder Adjustment	6.6	0.7	6.3	0.8
7. Shoulder Adjustment Velcro	6.2	1.1	6.1	1.0
8. Front Plate Pocket	6.5	0.8	6.9	0.3
9. Front Plate Pocket Velcro	6.5	0.7	6.5	0.7
10. Side Adjustment	6.6	0.5	5.9	1.4
11. Side Adjustment Velcro	6.1	1.1	5.5	1.6
12. Panel Pocket Velcro	6.1	1.0	6.0	1.0
13. Shell Material	6.8	0.4	6.6	0.7

Table 10: Gen III (Aug 99) Vest Features (Front)

1. Shoulder Pad Adjustment Strap	5.9	1.2	5.5	1.2
2. Shoulder Pad Snap (Back)	6.2	0.4	6.1	0.9
3. Rear Plate Pocket	6.7	0.5	6.8	0.4
4. Rear Plate Pocket Velcro	6.5	0.7	6.2	0.8
5. Side Elastic Limit Strap	6.4	0.7	5.7	1.2
6. Side Strap Pull Tab	6.6	0.7	6.1	1.3
7. Collar Snap	6.5	0.5	6.1	1.0

Table 11: Gen III (Aug 99) Vest Features (Back)

The durability and functionality of the features incorporated in the Gen III (Aug 99) vest were all rated as being acceptable.

4.6.2 Criteria of Importance

A criterion of importance questionnaire was administered during the Exit Focus Group. Participants rated the perceived importance of various design criteria for selecting or assessing a fragmentation vest. Participants ranked each criterion using a seven-point scale of importance. These ratings were then used to produce a criterion of importance ranking. Summary descriptive results (mean, standard deviation) are depicted in Figure 34 below. Criteria have been generally arranged in order of strongest to weakest importance.

The criteria of importance results are based upon the results of this trial and the knowledge base the participants brought to the trial. Since the trial was very limited, the specific results for these criteria of importance ranking are context and trial specific.

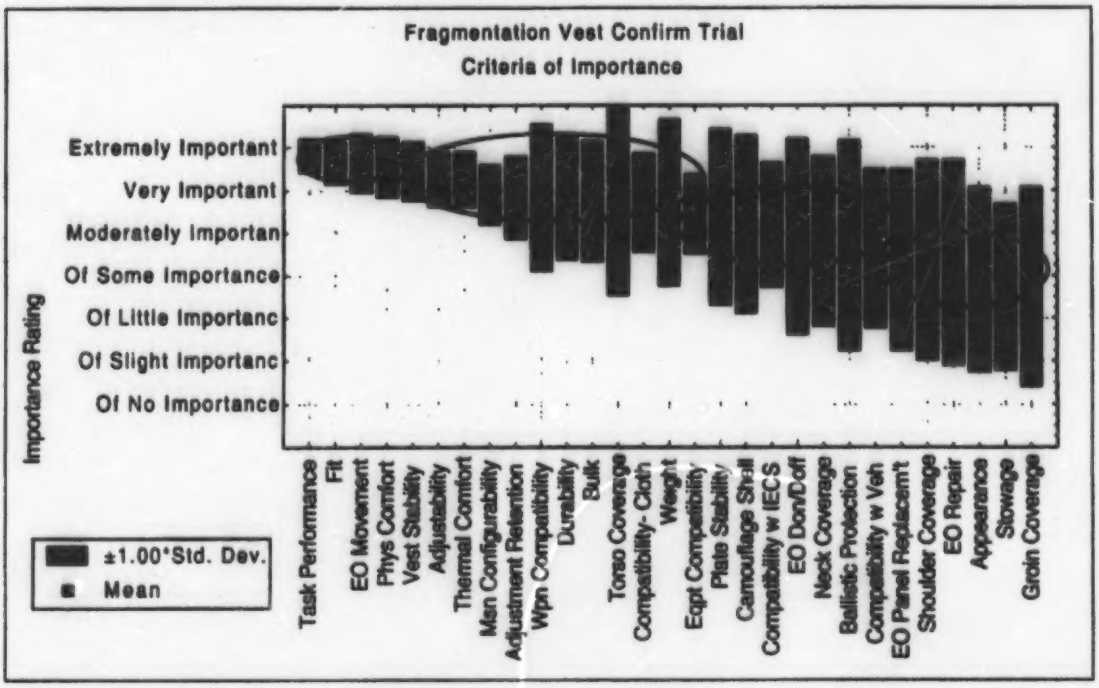

Figure 34: Criteria of Importance Questionnaire Results

4.6.2.1 Very Important to Extremely Important

Participants rated four criteria in the highest importance category: Task Performance, Fit, Ease of Movement, and Physical Comfort.

4.6.2.2 Very Important

Participants rated 11 criteria in this category: Adjustability, Bulk, Weight, Vest Stability, Thermal Comfort, Adjustment Retention, Torso Coverage, Mission Configurability, Durability, and Compatibility with Clothing and Weapon Compatibility.

4.6.2.3 Moderately Important

Participants rated eight criteria in this category: Equipment Compatibility, Plate Stability, Camouflage Shell, Ease of Donning and Doffing, Neck Coverage, Ballistic Coverage, IECS Compatibility, and Vehicle Compatibility.

4.6.2.4 Least Important

Participants rated six criteria in this category: Ease of Panel Replacement, Shoulder Coverage, Ease of Repair, Appearance, Stowage and Groin Coverage.

4.6.3 Exit Questionnaire

Participants were issued two similar Exit Questionnaires comparing all vest conditions against a number of HF criteria. Separate questionnaires were issued to allow for a direct vest comparison both with and without plates.

4.6.4 Vest Design Effects

Due to the limited number of subjects available only six subjects completed a direct comparison of the Gen III (Aug 99) vest against the Gen III (July 98) fragmentation vest. Overall the Gen III (Aug 99) vest was found to be compatible with both the TAV and the 82-pattern webbing. As discovered in previous trials (Reference F), subjects preferred the TAV load carriage condition to the 82-pattern condition.

4.6.4.1 Exit Questionnaire (Without Plates) – Vest Design Effects

The Gen III (July 98) and the Gen III (Aug 99) vests received a mean overall rating of "Reasonably to Completely Acceptable" rating in the Exit Questionnaire. Overall, participants rated the acceptability of the Gen III (Aug 99) vest significantly ($p < 0.05$) more acceptable the Gen III (July 98) vest. Results by vest conditions for each exit question are displayed below in Figure 35.

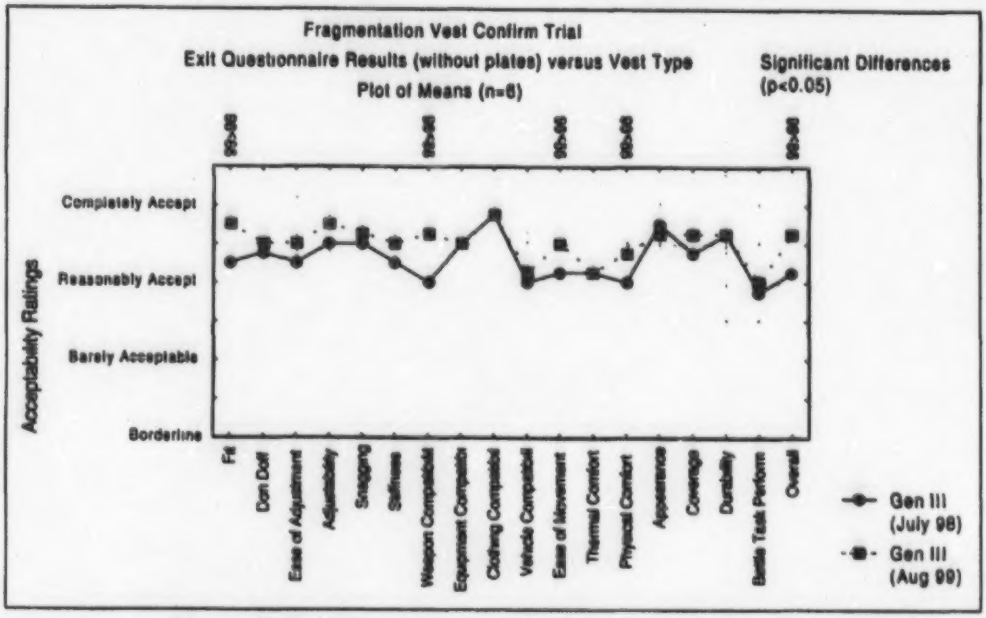

Figure 35: Exit Questionnaire (No-plates) Results (Vest Type Effects)

Subjects rated the Gen III (Aug 99) vest as being significantly more acceptable than the Gen III (July 98) vest for fit, weapon compatibility, ease of movement, physical comfort and overall acceptance.

4.6.4.2 Exit Questionnaire (With Plates) – Vest Design Effects

The Gen III (July 98) and the Gen III (Aug 99) vests with plates received a mean overall rating of "Barely to Reasonably Acceptable" in the Exit Questionnaire. There were no overall significant differences

between vest types with plates. Results by vest conditions for each exit question are displayed below in Figure 36.

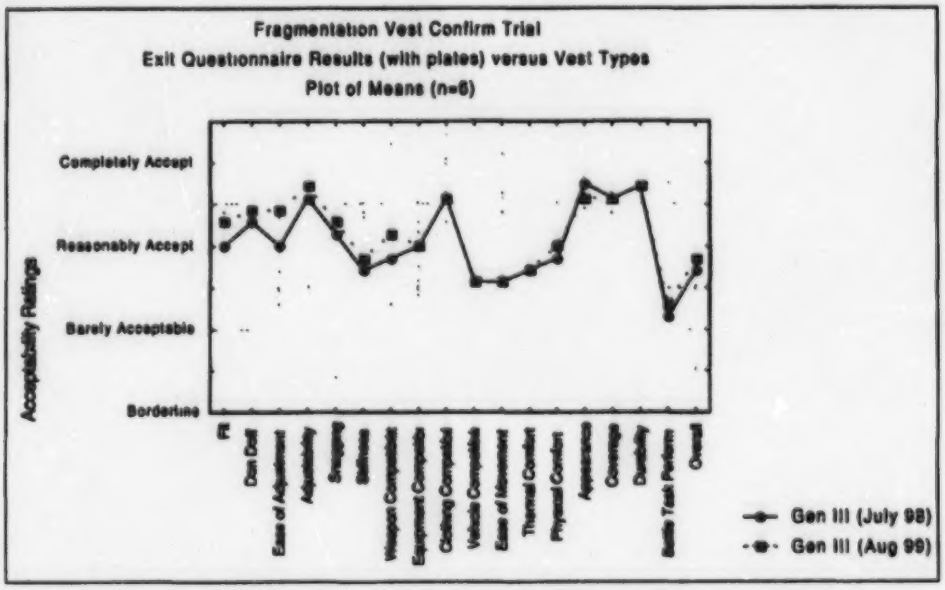

Figure 36: Exit Questionnaire (With-plates) Results (Vest Type Effects)

4.6.5 Load Carriage Effects

Due to limited numbers of subjects available only five subjects completed a direct comparison of the Gen III (Aug 99) vest against load carriage types. Overall the Gen III (Aug 99) vest was found to be compatible with both the TAV and the 82-pattern webbing. As discovered in previous trials (Reference F), subjects preferred the TAV load carriage condition to the 82-pattern condition.

4.6.5.1 Exit Questionnaire (Without Plates) - Load Carriage Effects

A post-hoc analysis of the Exit (Without Plate) Questionnaires identified a significant ($p < 0.05$) load carriage vest effect. Participants wearing the 82 pattern webbing rated the acceptability of the Gen III (Aug 99) vest significantly ($p < 0.05$) less acceptable (*Barely Acceptable*) than the participants wearing the TAV (*Reasonably to Completely Acceptable*). Results for the load carriage condition for each exit question are described below and displayed in Figure 37.

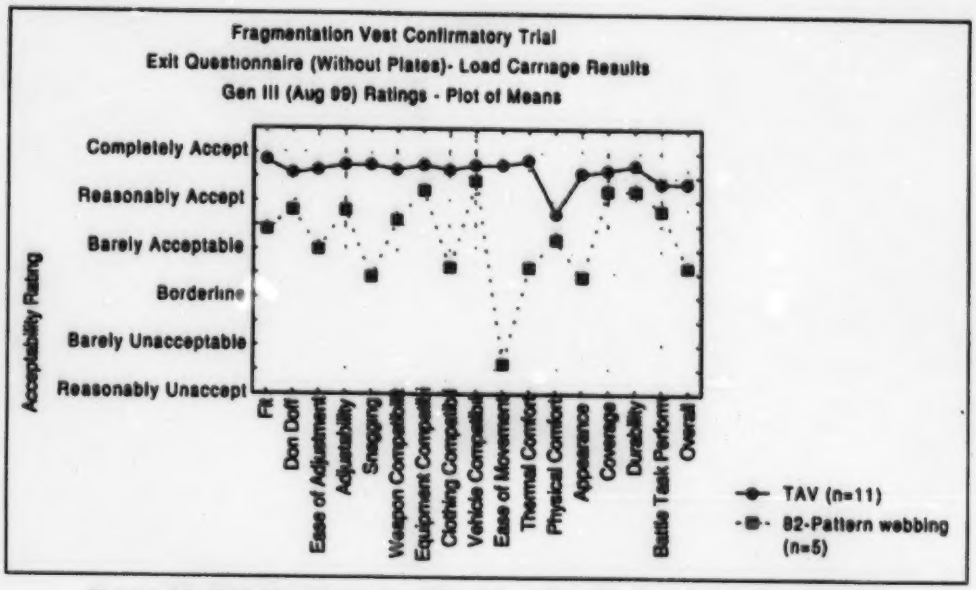

Figure 37: Exit Questionnaire (No-plates) Results (Load Carriage Effects)

Overall, there was a significant ($p < 0.05$) difference between the Exit Questionnaire results between the wearers of the 82-Pattern webbing and the TAV for the Gen III (Aug 99) vest without plates. The 82-Pattern webbing users rated Adjustability, Snagging, Thermal Comfort, Coverage and Durability (*Barely Acceptable to Reasonably Unacceptable*) significantly ($p < 0.05$) less acceptable than the TAV wearers for the Gen III (Aug 99) vest. Except for ease of movement with the 82-pattern webbing, the participants rated the Gen III (Aug 99) vest without plates in both the TAV and 82-Pattern webbing conditions as acceptable.

4.6.5.2 Exit Questionnaire (With Plates) – Load Carriage Effects

A post-hoc analysis of the Exit (With Plate) Questionnaires identified a significant ($p < 0.05$) load carriage vest effect. Participants wearing the 82 pattern webbing rated the acceptability of the Gen III (Aug 99) vest significantly ($p < 0.05$) less acceptable (*Barely Acceptable*) than the participants wearing the TAV (*Reasonably Acceptable*). Results for the load carriage condition for each exit question are described below and displayed in Figure 38.

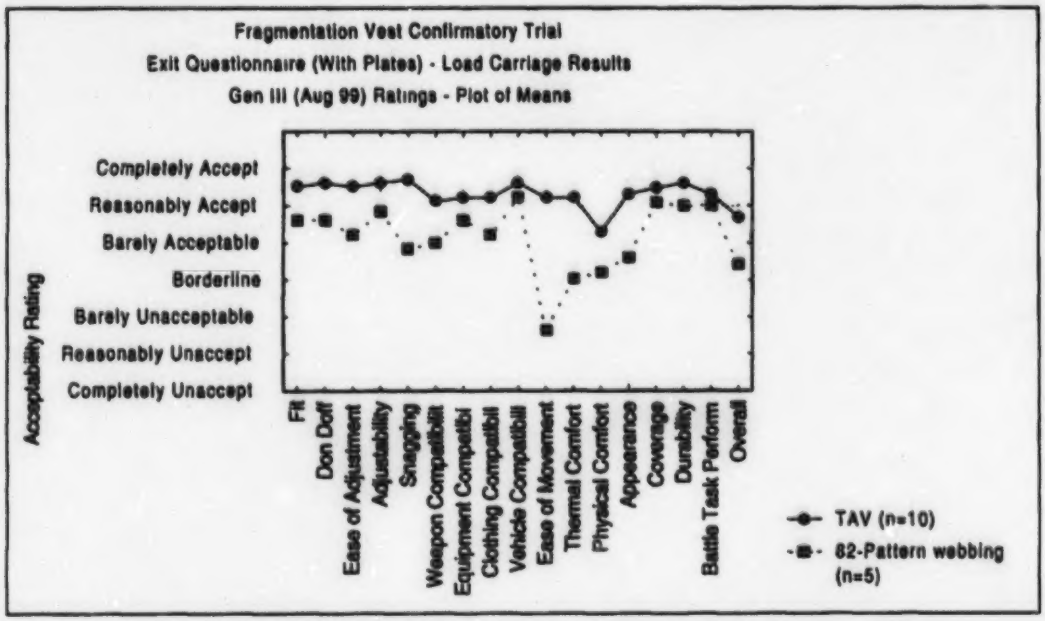

Figure 38: Exit Questionnaire (with plates) Results (Load Carriage Effects)

Overall, there was a significant ($p < 0.05$) difference between the Exit Questionnaire results between the wearers of the 82-Pattern webbing and the TAV for the Gen III (Aug 99) vest with plates. There were significant ($p < 0.05$) differences for all Exit Questions except for: Adjustability retention, equipment compatibility, vehicle compatibility, appearance, coverage and durability. Except for ease of movement with the 82-pattern webbing, the participants rated the Gen III (Aug 99) vest with plates in both the TAV and 82-Pattern webbing conditions as acceptable.

4.6.6 Exit Focus Group

All the participants agreed that the Gen III (July 98) or Gen III (Aug 99) fragmentation vests were significantly better than the various in-service and PASGT vests worn on UN missions. Participants indicated that although there was little difference between the Gen III (Aug 99) vest or the Gen III (July 98) vest, they preferred the Gen III (Aug 99) vest. This preference was as a result of different vest features and superior fitting vests. Subjects preferred having removable shoulder pads. An ability to reduce encumbrances while performing battle tasks was seen as being very important. Several subjects discovered that removing their shoulder pad gave them a more compatible rifle firing position. Removing the shoulder pad allowed them to tuck the rifle butt, tightly into their shoulder – see Figure 4. As well subjects found that by removing the shoulder pad and collar they could wear an IECS Parka overtop the vest and IECS middle layer jacket if required.

Universally subjects liked the non-slip material on the Gen III (Aug 99) vest. Caution was raised however, as to the durability of the mesh and whether the mesh opening size was the optimum.

A majority of subjects commented negatively on the shoulder pad design of the Gen III (Aug 99) design. While the design eliminated the potential pressure points caused by the adjustment design incorporated in the Gen III (July 98) design, it created new problems. Frequently the shoulder pad reduced arm freedom

of movement, especially when raising the arms up. As well, the Gen III (Aug 99) design resulted in a significant gap in protection between the upper shoulder and upper arm. The Gen III (Aug 99) shoulder pad design twisted out of place more often than the Gen III (July 98) design when donning and doffing the TAV. The subjects preferred the Gen III (July 98) design or failing this, redesign the Gen III (Aug 99) design to make the shoulder pad fit higher and tighter to the shoulder.

A number of subjects found that the fixed collar on the Gen III (July 98) vest caused chaffing. All subjects preferred the option of removing the neck guard to enhance freedom of movement especially while driving vehicles, traversing obstacles, FIBUA operations, etc. While the subjects preferred a removable collar option, the Gen III (Aug 99) collar did not appear to offer as much protection as The Gen III (July 98) vest. The design of the collar on the Gen III (Aug 99) vest stood-up much more than the Gen III (July 98) vest causing chaffing, especially in the prone C7A1 firing position. These subjects recommended that the detachable collar be refined to lower its aspect and to provide a better ballistic seal at the bottom.

Two subjects commented on the high neckline of the Gen III (Aug 99) vest which caused some choking and neck irritations especially while wearing plates. The subjects recommended that the neckline should be lowered if at all possible.

Several subjects commented on pressure points and chaffing with the Gen III (July 98) and Gen III (Aug 99) designs under the arms. Although the vests were flexible, these subjects believed that prolonged wear may indicate that the arm opening as cut too tight. Chaffing was most apparent when performing the prone C7A1 rifle firing task and the vehicle compatibility task. When adopting a prone fire position, the vests would ride up until locked at the arm opening. Similarly when driving the vests would bunch up under the arms. The subjects recommended enlarging the arm opening if possible.

While the subjects preferred the Gen III (Aug 99) vest over the Gen III (July 98) vest for its ability to achieve a tighter fit, the subjects were concerned with the durability of Velcro and elastic straps. . The longer Velcro hook panels on the Gen III (Aug 99) vest were preferred to the shorter panels on the Gen III (July 98) vest. The subjects were sceptical as to whether Velcro or elastic straps will be durable enough for prolonged field operations.

All the participants felt that with minor tweaking either the Gen III (July 98) or the Gen III (Aug 99) vest were suitable for fielding.

All but one subject commented positively on the TAV load carriage system. The TAV systems were more compatible with the fragmentation vests than the 82-pattern webbing systems. Yoke straps slid off the shoulders of the vests when wearing 82-pattern webbing.

All of the subjects found the black vests to be hot to wear in 30°C weather. When not performing battle drills or traversing obstacles subjects frequently removed their vests. The use of TAVs limits the ability of users to loosen off the sides of the vest to enhance ventilation.

All of the subjects believed that the stiffness of the vest shell material and ballistic panels were acceptable.

5. Discussion

A one and one-half day confirmatory trial evaluation of the Gen III (Aug 99) fragmentation vest was undertaken to quickly determine the efficacy of previous design changes to the Gen III (July 98) fragmentation vest. As well, the trial was under taken to see if a change in shell material would improve user acceptance of the vests developed for the fragmentation fit and tariff trial. The fragmentation vest fit trial vests were modified by replacing the very stiff CADPAT shell material with 500 and 1000 Denier cordura. The design changes to the Gen III (July 98) vest included:

- Removal of some material around the arm openings.
- Provision of a removable collar.
- Changes to the Shoulder Pad Retention system
- Provision of slip resistant material on shoulder pads and butt rest points
- Lengthening of the Side Adjustment Strap Velcro pile on the front of the vest.

The changes to a more flexible shell material greatly reduced the significance of the arm opening problems reported in the previous vest fitting trial (Reference J). While the removal of approximately 1.2 cm around the arm opening of the Gen III (July98) vest alleviated some of the arm opening problems reported in the earlier human factors trial (Reference F), a number of subjects still commented on too tight a fit. Unlike previous trials lasting five days or more, this confirmatory trial lasted just on and one-half days. It is possible that given longer exposure, more subjects may identify that the arm openings are still too small. Thus although enlarging the arm opening further will reduce ballistic protection, the small changes in coverage at the critical arm opening may significantly enhance user comfort and acceptance.

Significant numbers of subjects in the fit trial commented that the neckline was too high and recommended that it be lowered if at all possible. The neckline on the Gen III (Aug 99) vest wasn't changed from the previous iteration and a number of subjects still reported problems. Although changes to the vest shell stiffness may have reduced the numbers of complaints with the neckline, it still hasn't eliminated them. As discussed above, previous trials lasted considerably longer than one day of wear and given more exposure, more subjects may identify that the neckline is still too high.

The subjects were supportive of the change to a removable collar. The cut of the collar should be examined to insure that it doesn't cause gaps in coverage at the lower neck.

The participants in the confirmatory trial did not support the changes to the shoulder pad design. The redesigned shoulder pad was too loose, tended to tangle and caused gaps in coverage. The subjects preferred the Gen III (July 98) shoulder pad design. Although the shoulder pad design was better in the original vest, the dot fastener positions on the Gen III (Aug 99) design were better located than those of the Gen III (July 98) design.

The subjects supported the provision of non-slip material on the shoulders. The non-slip material helped prevent rifle butt slippage.

The subjects approved of the lengthening of the Velcro pile on the front of the vest. The longer strip allowed users to secure the side adjustment straps or permitted them to get a tighter fitting vest.

All the subjects commented that the stiffness of the Gen III (Aug 99) or the Gen III (July 98) vest shell materials were acceptable.

6. Recommendations

Based on the results of this confirmatory trial of the Gen III (Aug 99) fragmentation vests, we recommend that the following Gen III (July 98) design changes should be accepted:

- Removal of the material around the arm openings.
- Provision of a removable collar.
- Provision of slip resistant material on shoulder pads and butt rest points
- Lengthening of the Side Adjustment Strap Velcro pile on the front of the vest.

The change to the shoulder pad design was not accepted. It is recommended that the Gen III (July 98) shoulder pad design should be utilized with the Generation III (Aug 99) shoulder pad snap locations. The trialled shell stiffness was found to be acceptable. The 500 and 1000 denier cordura with a kiss coating eliminated many of the problems associated with the CADPAT shell material.

While the results of this confirmatory trial also indicate the need for additional refinements to the fragmentation vest (changes to the arm opening, lower the neck height, and improvements to the collar), the very limited nature of the confirmatory trial suggests caution. It is recommended that any other modifications wait until after the bid acceptance trial. The fragmentation vest bid trial will permit a better evaluation of the concerns with the neck height, arm opening and collar design. If comments from the bid trial support the need to refine the design then changes to the technical data package can be made at that time without slowing the procurement or bid acceptance process.

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14 ABSTRACT

(U) In 1991, the Canadian Forces (CF) designed and built a fragmentation vest for the protection of our Land Forces personnel against ballistic threats during military operations. Operational deficiencies with the fragmentation vest were reported shortly after introduction into service, these deficiencies included excessive stiffness, degraded mobility, and incompatibility with helmets, weapon sights and in-service personal load carriage equipment. In order to resolve the in-service vest deficiencies, a series of human factors (HF) investigations were undertaken to develop a new fragmentation vest design. Once a basic design was finalized it was recommended that a detailed fit test should be undertaken to determine tariff and fit boundaries and a confirmatory trial should be undertaken to evaluate the efficacy of any design changes.

A one and one-half-day field trial was undertaken at CFB Petawawa over the period 01 to 02 September 2000 (Reference F) to confirm design changes to the Generation III fragmentation vest. Two fragmentation vest systems were evaluated by a total of 11 regular force male participants. A partially repeated measures comparison between vest conditions was performed. The human factors tests included assessments of fit, weapon, clothing and equipment compatibility, performance of selected obstacle and combat tasks, battle tasks, comfort, and user acceptance.

Based on the results of the confirmatory trial a number of previously recommended design changes were supported while some were rejected The following recommended changes were confirmed as being beneficial removal of the material around the arm openings, provision of a removable collar, provision of slip resistant material on shoulder pads and butt rest points, and lengthening of the side adjustment strap Velcro pile on the front of the vest The proposed change to the shoulder pad design was not supported It is recommended that the Gen III (July 98) shoulder pad design should be utilized with the Generation III (Aug 99) shoulder pad snap locations The trailed vest carrier shell stiffness was found to be acceptable The 500 and 1000 denier cordura with a lusa coating eliminated many of the problems associated with the CADPAT shell material utilized in the fitting trial The results of the confirmatory trial also indicate the need for additional refinements to the vest design but it was recommended that any other modifications wait until after the bid acceptance

15 KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) Generation III Fragmentation Vest; Fragmentation Vest, Ballistic Vest; Ballistic Protection, Clothe the Soldier, Human Factors Evaluation, Generation II Fragmentation Vest, Field Trial